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            - Authentication
            - Authorization

        - Models
    - Logging

Basics

HTTP

Request

Structure

Line 1 - request method, uri, http version

> Method Request-URI HTTP-versio

Body

Headers - host, accept, authentication, user-agent...

Cookies - http is stateless-this serves as a state

Response

> HTTP-version Status-code Reason-phrase

Versions

/2 multiplexing, HTTPS "only"

/3 not widely supported

HTML

html, head, title, /head, body, /body, /html

DOM Tree in infix serialization

WWW ~ Web of documents

Hyperlinks - resource references

Headings - section/article edit its size

Tables - care with colspan, rowspan

Meta elements

Forms

```
<form method="get" action="http://www.example.org/newcustomer.php">
    Name: <input name="fullname" ... >
    Phone: <input name="phone" ... >
    Preferred delivery time: <input name="time" ... >
    Comments: <textarea name="comments"></textarea>
    <button type="submit">Submit Order</button>
</form>
```

Controls:

- input
  - type
- textarea
- select
- button

Attributes:

- name
- value

Other attributes

- maxlength
- pattern
- required
- placeholder
- autocomplet

CSS

Styles assigned to elements

- Inlined styles `<h1 style="color: red;">Red Heading</h1`
- `<style>` element in head
- linking from external file: `<link rel="stylesheet" type="text/css" href="styles.css">`

Selectors

- by name
  - `p`
- by id
  - `#theId`
- by class
  - `.theClass`
- universal
  - `*`

Combining:

- `div.inf`
  - all div elements with class info
- `h1#main`

  - h1 element with id main

Relative positions

- space
  - `E F`
    - F has ancestor E
- gt sign
  - `E > F`
    - E is (direct) parent of F
- plus
  - `E + F`
    - F immediately preceeded by E
- tilde
  - `E ~ F`
    - F preceeded by E

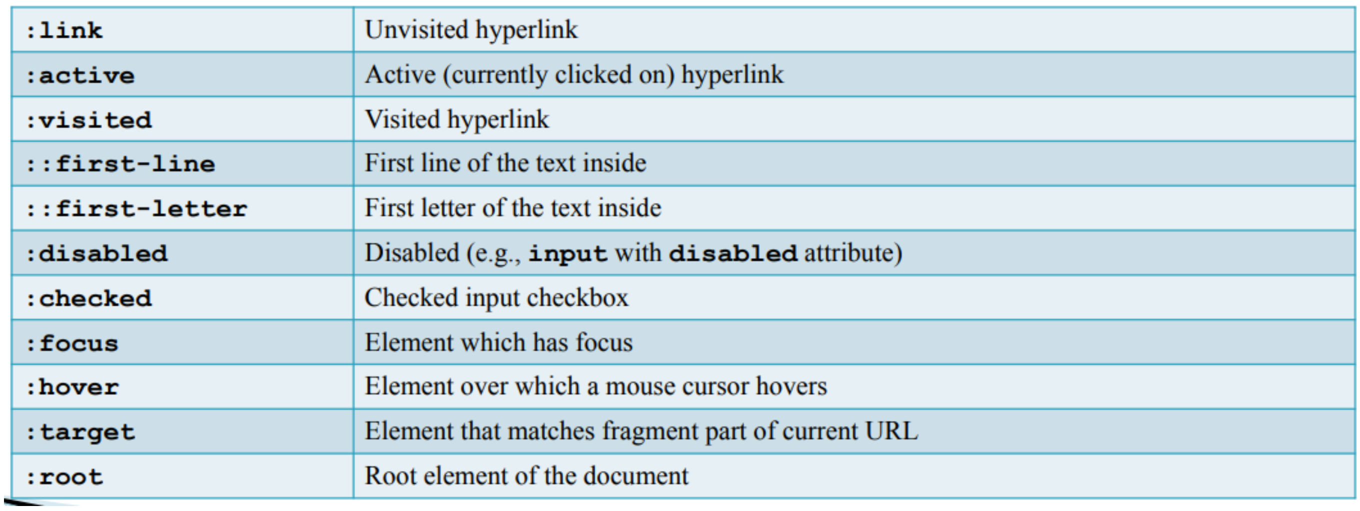
Aggregation:

- comma
  - `s1, s2`
    - use for s1 or s2

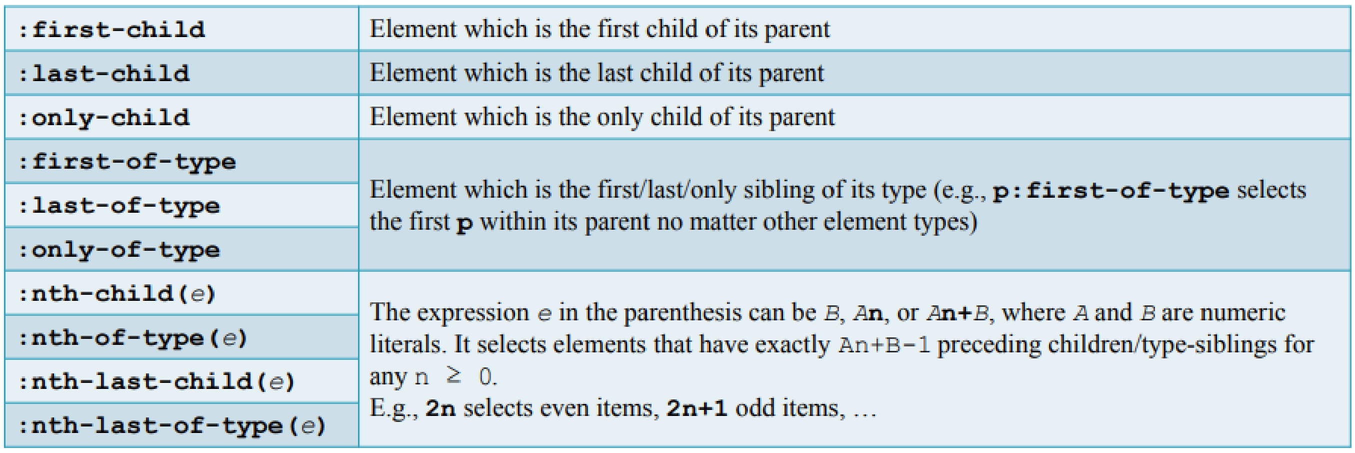
Pitfalls

- `ul li` vs `ul > li`
- `p.info` vs `p .info`
- `main ul, ol`

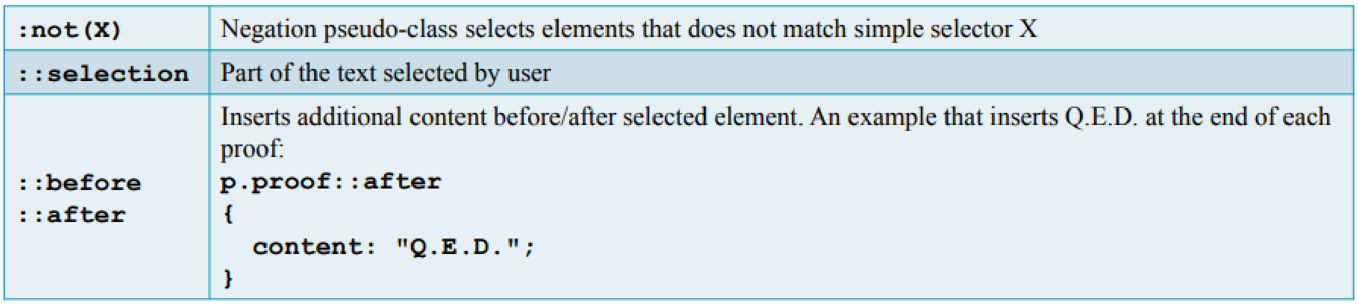
Pseudo-classes selectors:



`:link`	Unvisited hyperlink
`:active`	Active (currently clicked on) hyperlink
`:visited`	Visited hyperlink
`::first-line`	First line of the text inside
`::first-letter`	First letter of the text inside
`:disabled`	Disabled (e.g., **`input`** with **`disabled`** attribute)
`:checked`	Checked input checkbox
`:focus`	Element which has focus
`:hover`	Element over which a mouse cursor hovers
`:target`	Element that matches fragment part of current URL
`:root`	Root element of the document



`:first-child`	Element which is the first child of its parent
`:last-child`	Element which is the last child of its parent
`:only-child`	Element which is the only child of its parent
`:first-of-type`	Element which is the first/last/only sibling of its type (e.g., **`p:first-of-type`** selects the first **p** within its parent no matter other element types)
`:last-of-type`	
`:only-of-type`	
`:nth-child(e)`	The expression *e* in the parenthesis can be *B*, *A***n**, or *A***n+***B*, where *A* and *B* are numeric literals. It selects elements that have exactly `An+B-1` preceding children/type-siblings for any `n ≥ 0`. E.g., **2n** selects even items, **2n+1** odd items, …
`:nth-of-type(e)`	
`:nth-last-child(e)`	
`:nth-last-of-type(e)`	



`:not(X)`	Negation pseudo-class selects elements that does not match simple selector X
`::selection`	Part of the text selected by user

`::before`
`::after`
	Inserts additional content before/after selected element. An example that inserts Q.E.D. at the end of each proof:
	`p.proof::after`
	`{`
	`   content: "Q.E.D.";`
	`}`

Cascading

1. Transition declarations (will be explained later)
2. Important user agent declarations
3. Important user declarations
4. Important override (by client-script) declarations
5. **Important author declarations**
6. Animation declarations (will be explained in adv. lectures)
7. Normal override declaration
8. **Normal author declarations**
9. Normal user declarations
10. Normal user agent declarations

Specificity either by the number the different selectors and if same, then the latest declared.

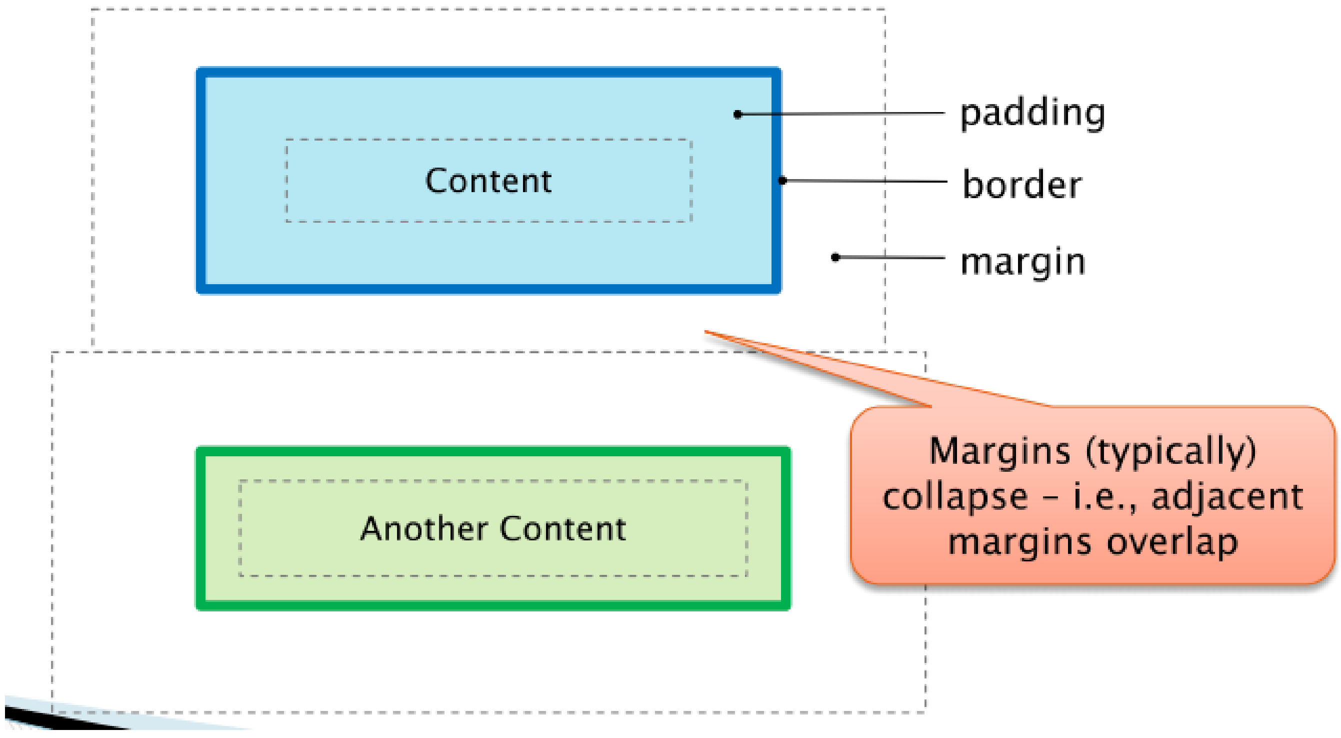
Properties

Fonts, colorsD

Display

- block
- inline
- inline-block
- none
- list-item
- table, table-*

Box model


Content
padding
border
margin
Another Content
Margins (typically) collapse – i.e., adjacent margins overlap

Floating elements

`float: clear`

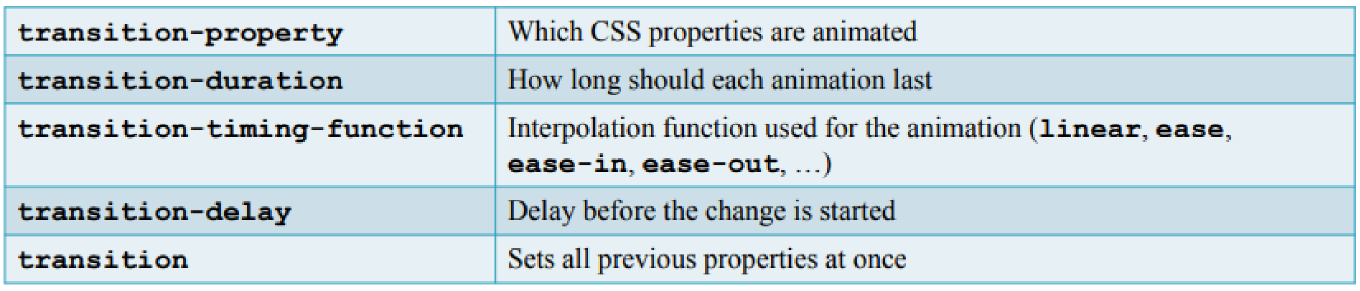
Filters

Transformations

Some predefined, can use `matrix()`

Transitions

For simple animations - between 2 states



`transition-property`	Which CSS properties are animated
`transition-duration`	How long should each animation last
`transition-timing-function`	Interpolation function used for the animation (**`linear`**, **`ease`**, **`ease-in`**, **`ease-out`**, ...)
`transition-delay`	Delay before the change is started
`transition`	Sets all previous properties at once

Animations

Multiple states

Media

Media Limitations

- Restricting styles for particular visualization medium

Media Types

- Select style sheets for particular media
    - screen, print, speech, ...

Media Features (Properties)

- Add additional conditions to the types
    - width, height
    - device-width, device-height
    - orientation, aspect-ratio

Layout

Variable - `--varName`

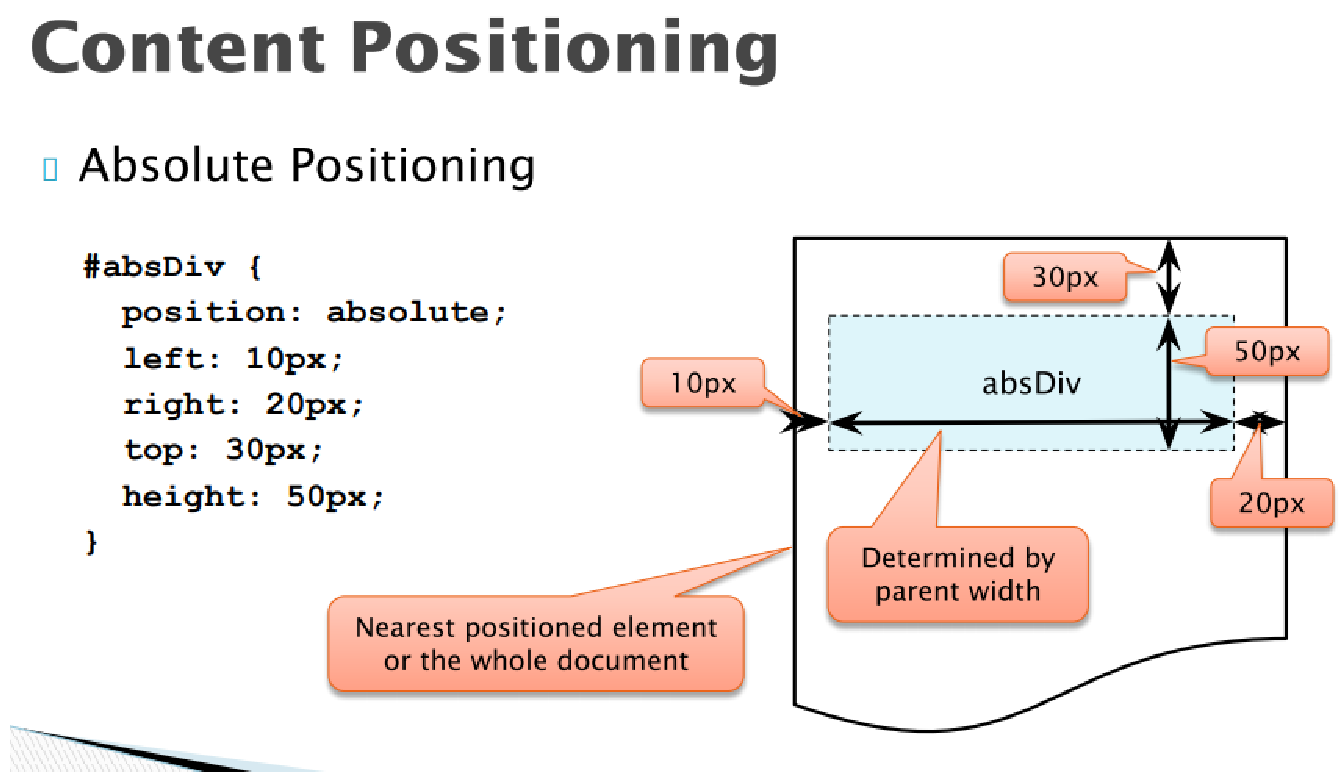
- access via: `var()`

Calculations

- `calc()`

Counters:

```css
body { counter-reset: chapter; }
h1 { counter-reset: section; }
h2 { counter-reset: subsection; }
h1::before {
  content: "Chapter " counter(chapter) ": ";
  counter-increment: chapter;
  color: #900;
}
h2::before {
  content: counter(chapter) "." counter(section) " ";
  counter-increment: section;
}
h3::before {
  content: counter(chapter) "." counter(section) "."
           counter(subsection) " ";
  counter-increment: subsection;
}
```



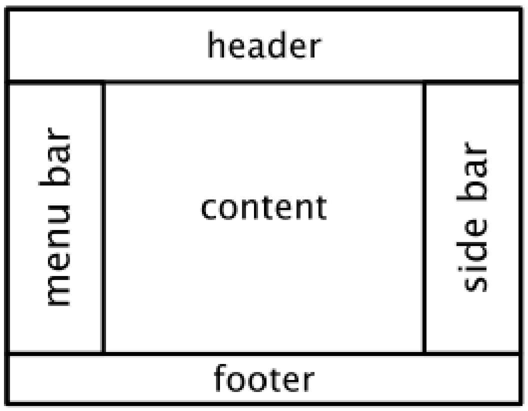
Content Positioning

- Absolute Positioning

```
#absDiv {
  position: absolute;
  left: 10px;
  right: 20px;
  top: 30px;
  height: 50px;
}
```

30px
50px
10px
absDiv
20px
Determined by parent width
Nearest positioned element or the whole document

Basic layout

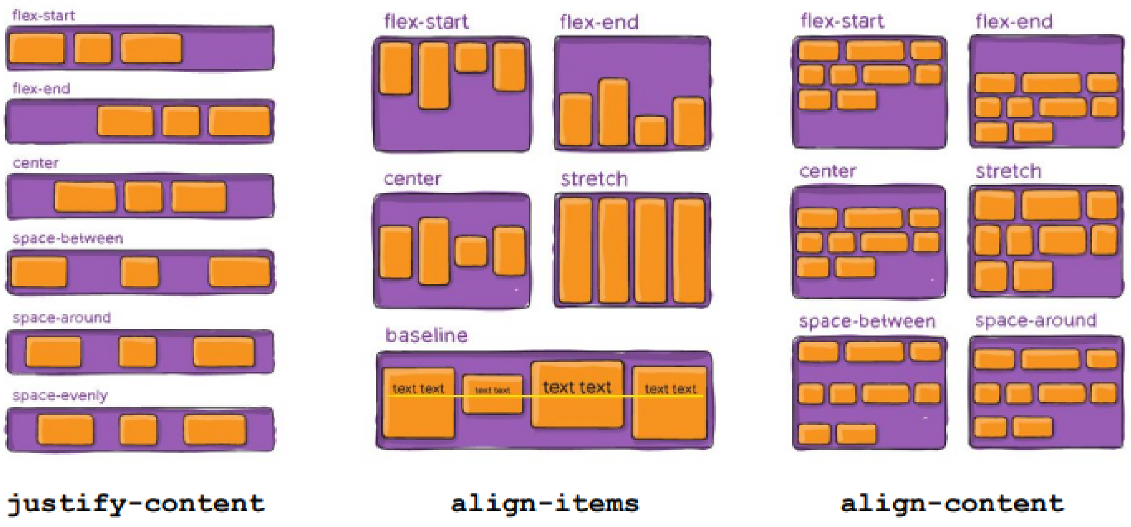


Modern layout

Flex box

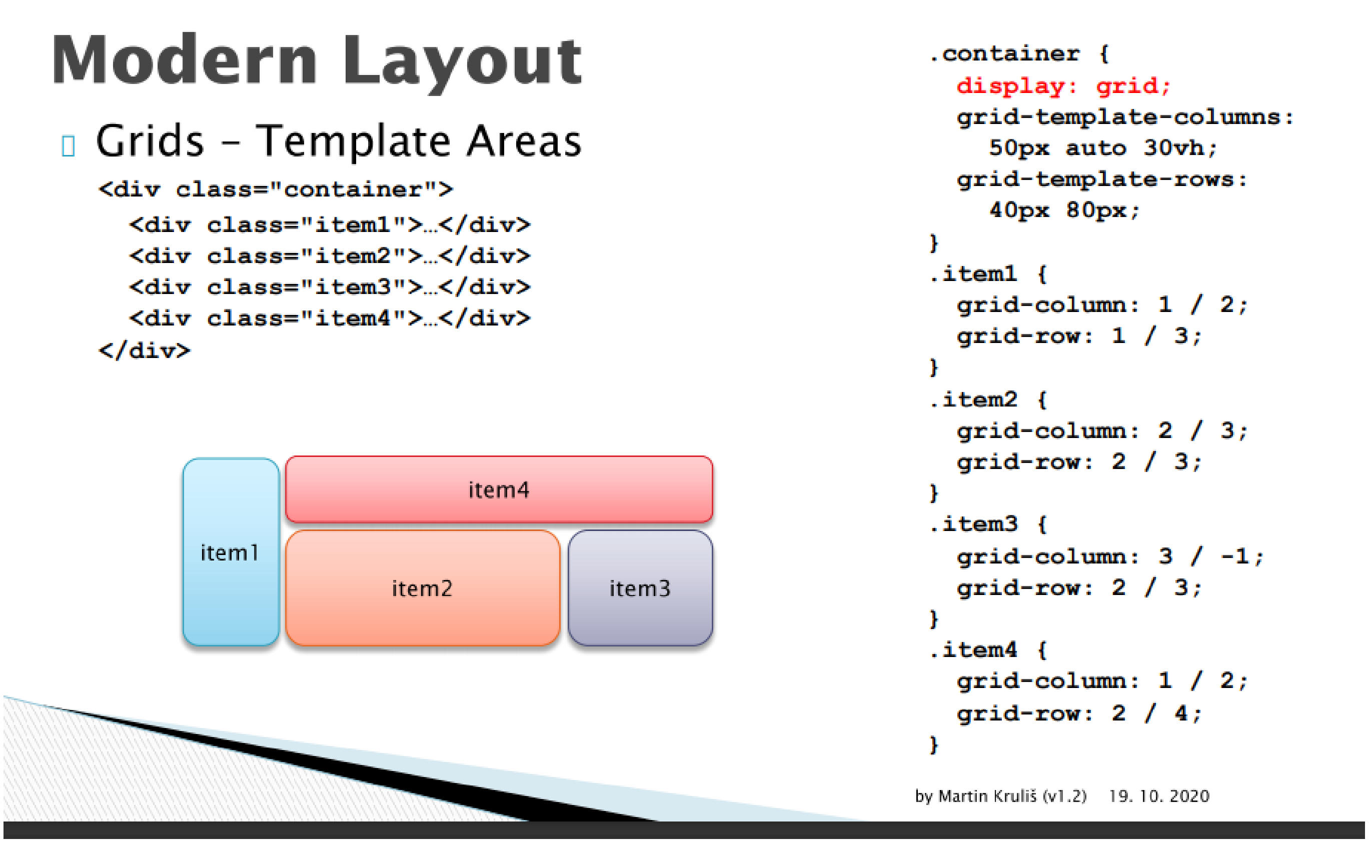
Flow of UI controls

Flex - Examples



Grid layout

Larger regular layouts



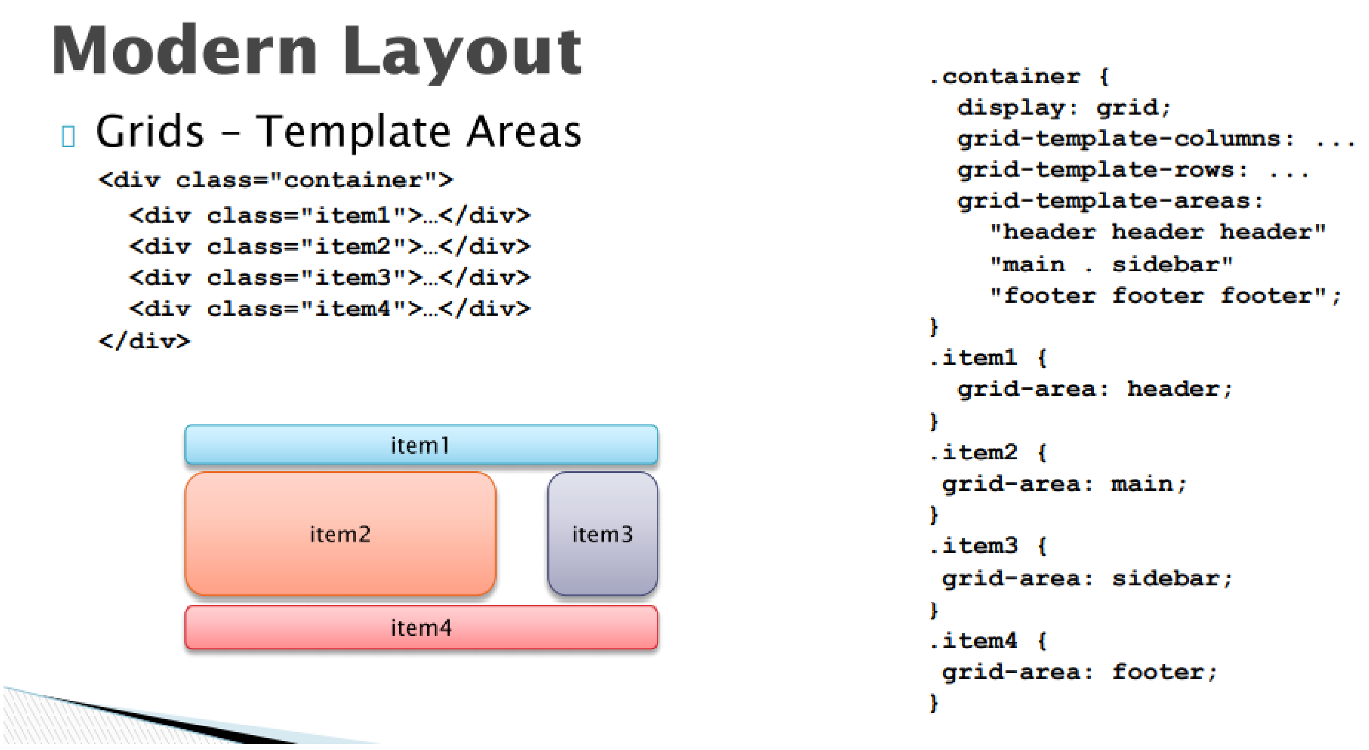
Modern Layout

- Grids – Template Areas

```
<div class="container">
  <div class="item1">…</div>
  <div class="item2">…</div>
  <div class="item3">…</div>
  <div class="item4">…</div>
</div>
```

```
.container {
  display: grid;
  grid-template-columns:
    50px auto 30vh;
  grid-template-rows:
    40px 80px;
}
.item1 {
  grid-column: 1 / 2;
  grid-row: 1 / 3;
}
.item2 {
  grid-column: 2 / 3;
  grid-row: 2 / 3;
}
.item3 {
  grid-column: 3 / -1;
  grid-row: 2 / 3;
}
.item4 {
  grid-column: 1 / 2;
  grid-row: 2 / 4;
}
```

by Martin Kruliš (v1.2) 19. 10. 2020



Modern Layout

- Grids – Template Areas

```
<div class="container">
  <div class="item1">…</div>
  <div class="item2">…</div>
  <div class="item3">…</div>
  <div class="item4">…</div>
</div>
```

```
.container {
  display: grid;
  grid-template-columns: ...
  grid-template-rows: ...
  grid-template-areas:
    "header header header"
    "main . sidebar"
    "footer footer footer";
}
.item1 {
  grid-area: header;
}
.item2 {
 grid-area: main;
}
.item3 {
 grid-area: sidebar;
}
.item4 {
 grid-area: footer;
}
```

Hacks

- to center element: `margin-left: auto; margin-right: auto`
- pre-`box-sizing`
  - martyoshka
    - double up `<div>`, outer width+margin and inner padding and border

Responsive web

- use relative widths in `%`
- or use style sheets per different devices - use `media`

Frameworks

- e.g. twitter bootstrap

Issues with CSS

- not DRY (dont repeat yourself) friendly
  - solution - preprocessing
    - LESS and SASS (Syntactically Awesome Stylesheets)

SASS (Syntactically Awesome Stylesheets)

Inheritance, variables, possible de-nesting of structures:

```
nav {
    ul {
        margin: 0;
        li {
            display: inline-block;
        }
    }
    a {
        color: green;
    }
}
```

VS

```


nav ul {
    margin...
}
nav ul li {
    display...
}
nav a {
    color...
}
```

Web Applications Fundamentals and Server-side Technologies

CGI ~ common gateway interface - mostly server side

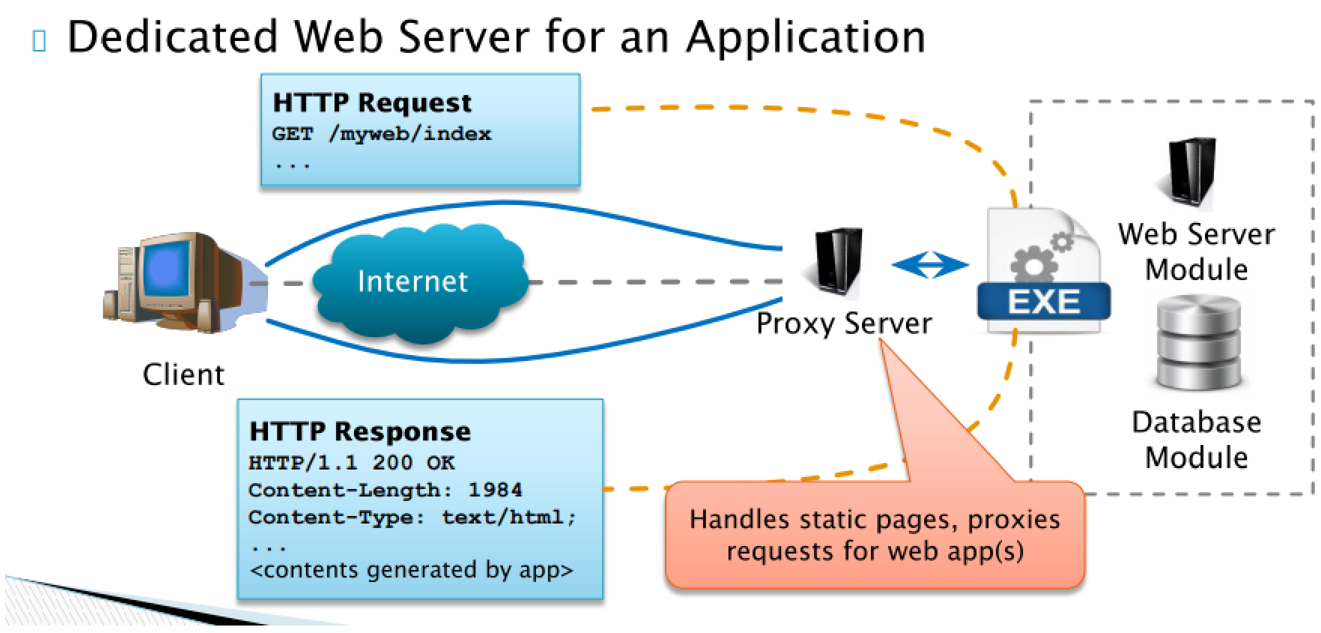
Scripting languages popular, already necessary on client side

- drawback is speed

Platforms

- ASP.NET
  - WebForms
  - Razor - cshtml
  - MVC
- JSP (Java Server Pages)
  - almost dead, lol (Spring boot, JSF)
- Ruby on Rails
  - Convention over Configuration

Integrated Web Server



Dedicated Web Server for an Application

```
HTTP Request
GET /myweb/index
...
```

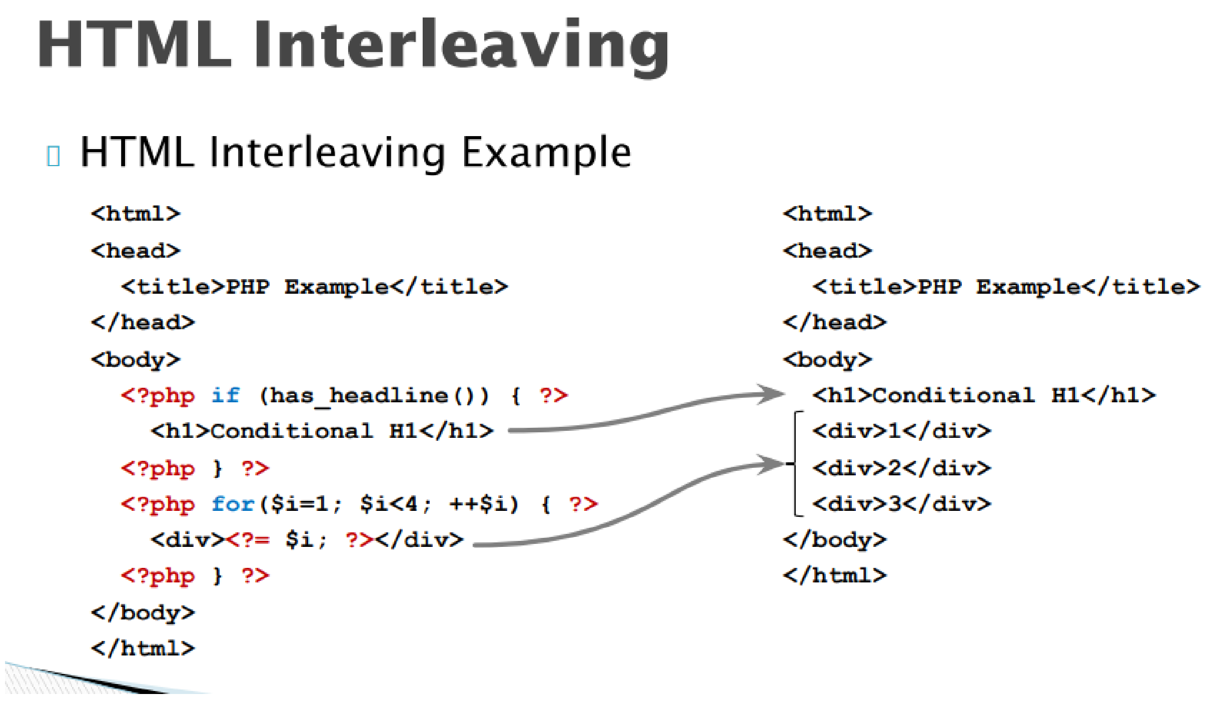
```
HTTP Response
HTTP/1.1 200 OK
Content-Length: 1984
Content-Type: text/html;
...
<contents generated by app>
```

Node.js

- Server-side JS platform

PHP

interleaving with HTML or standalone scripts



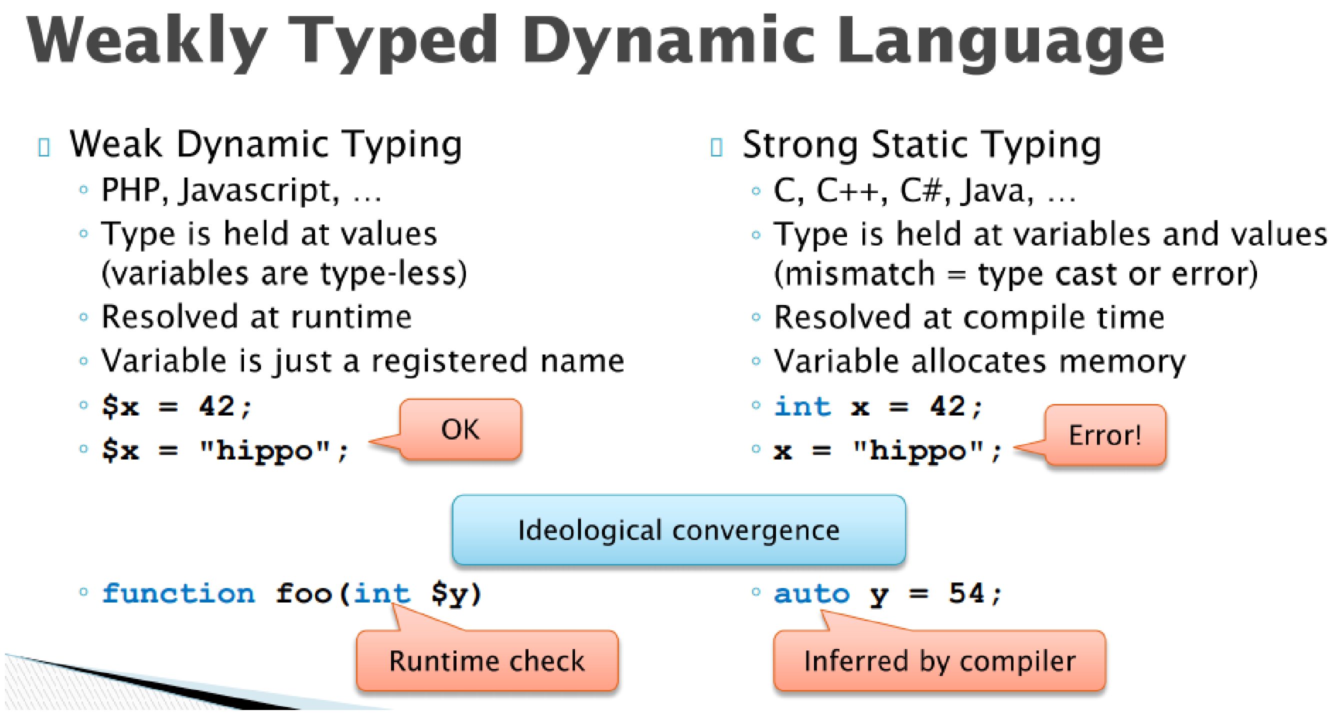
HTML Interleaving

- HTML Interleaving Example

```
<html>
<head>
  <title>PHP Example</title>
</head>
<body>
  <?php if (has_headline()) { ?>
    <h1>Conditional H1</h1>
  <?php } ?>
  <?php for($i=1; $i<4; ++$i) { ?>
    <div><?= $i; ?></div>
  <?php } ?>
</body>
</html>
```

```
<html>
<head>
  <title>PHP Example</title>
</head>
<body>
  <h1>Conditional H1</h1>
  <div>1</div>
  <div>2</div>
  <div>3</div>
</body>
</html>
```

Language differences



Weakly Typed Dynamic Language

- Weak Dynamic Typing
  - PHP, Javascript, …
  - Type is held at values (variables are type-less)
  - Resolved at runtime
  - Variable is just a registered name
  - `$x = 42;`
  - `$x = "hippo";`
  - `function foo(int $y)`
- Strong Static Typing
  - C, C++, C#, Java, …
  - Type is held at variables and values (mismatch = type cast or error)
  - Resolved at compile time
  - Variable allocates memory
  - `int x = 42;`
  - `x = "hippo";`
  - `auto y = 54;`

Variables

Variables - `$thisIsAVariable`

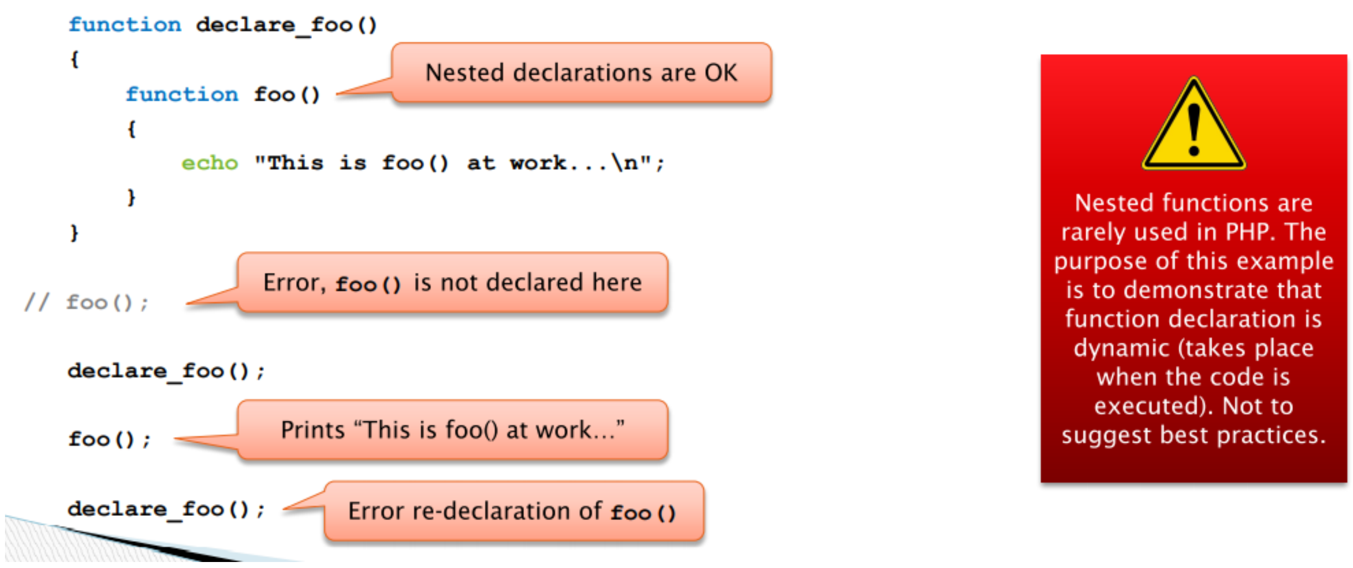
Types

- Scalar (`boolean`, `integer`, `float`, or `string`)
- Compound (`array`, `object`)
- Special (`resource`, `NULL`)

String Literals

- Single quoted strings ('text') – no special treatment
- Double quoted strings ("text") – interpreted
  - Special escaped characters (\n, \r, \t, ...)
  - Variables are replaced by their contents
  - `$a = 'foo'; $b = "Say $a\n";`

Functions



```
function declare_foo()
{
    function foo()
    {
        echo "This is foo() at work...\n";
    }
}

// foo();

declare_foo();

foo();

declare_foo();
```

Nested declarations are OK

Error, `foo()` is not declared here

Prints “This is foo() at work…”

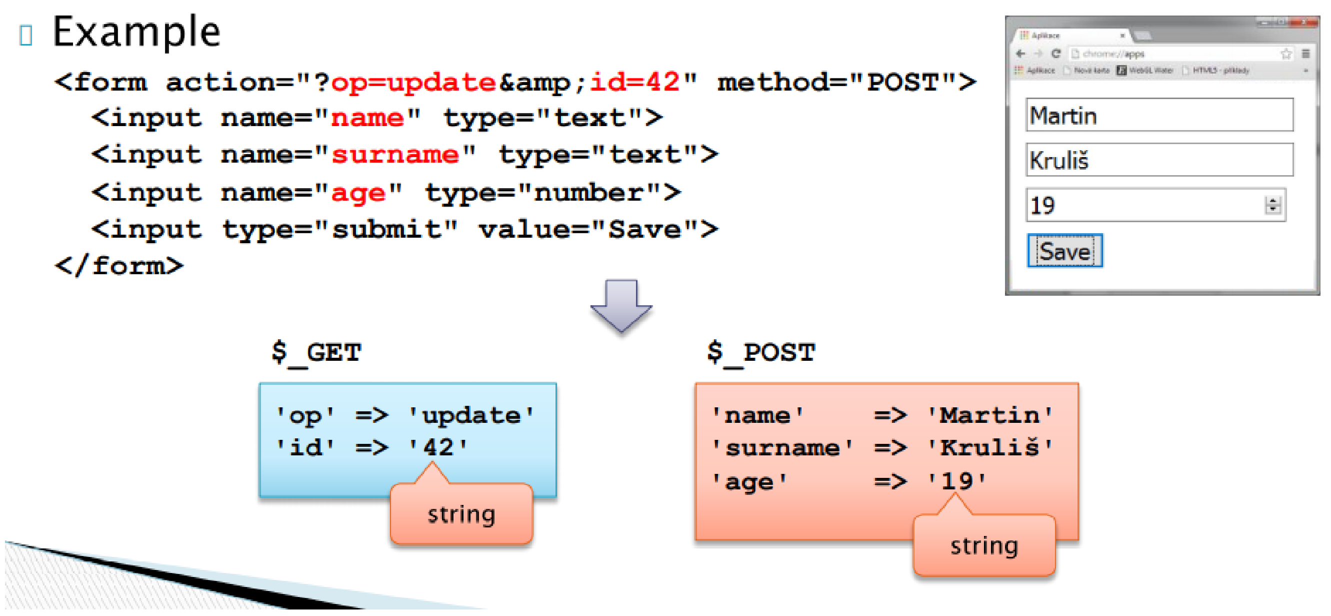
Error re-declaration of `foo()`

Nested functions are rarely used in PHP. The purpose of this example is to demonstrate that function declaration is dynamic (takes place when the code is executed). Not to suggest best practices.

HTTP Wrapper

`$_GET` / `$_POST` and others...

- `REQUEST_METHOD` (GET/POST)
- `SERVER_PROTOCOL` (HTTP/1.1)
- `REQUEST_URI` (/index.php)
- `REMOTE_ADDR`
- `HTTP_ACCEPT`
- `HTTP_ACCEPT_LANGUAGE`
- `HTTP_ACCEPT_ENCODING`
- `HTTP_ACCEPT_CHARSE`



Example

```
<form action="?op=update&amp;id=42" method="POST">
  <input name="name" type="text">
  <input name="surname" type="text">
  <input name="age" type="number">
  <input type="submit" value="Save">
</form>
```

Martin
Kruliš
19
Save

$_GET

```
'op' => 'update'
'id' => '42'
```

string

$_POST

```
'name'    => 'Martin'
'surname' => 'Kruliš'
'age'     => '19'
```

string

Arrays

```
$a = [ 'a', 4 => 'b', 'c' ];
$a[42] = 'd';
$a[] = 'e';
// [ 0=>'a', 4=>'b', 5=>'c', 42=>'d', 43=>'e' ]
```

Variable variables

`$a = 'b'; $$a = 42; // the same as $b = 42;`

References

```
$a = 1;
$b = &$a;
$b++;
echo $a;
// prints 2
```

Functions

Type hinting in arguments - at least some runtime check.

No overloading, can be overridden

Indirect calling

```
function foo($x, $y) { … }
$funcName = 'foo';
$funcName(42, 54); // the same as foo(42, 54)
```

```
call_user_func('foo', 42, 54)
```

Anonymous functions

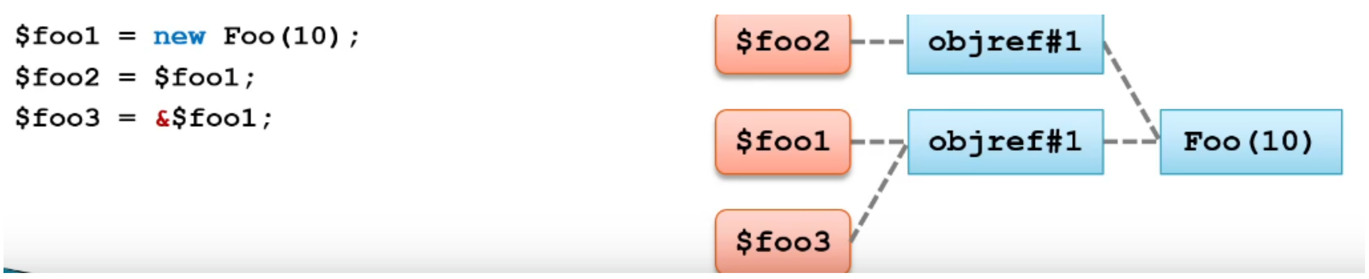
Nameless, lambda eqviv but obsolete

```
$fnc = function ($arg) { …body… };
$fnc(42)
```

OOP in PHP

```
class Foo {
    public $var = 0; // a member variable

    public function bar() { // a method
        echo $this->var;
    }
}
$instance = new Foo(); // create new instance
$instance->var = 42;
$instance->bar();
$instance = null;
```

References



```
$foo1 = new Foo(10);
$foo2 = $foo1;
$foo3 = &$foo1;
```

Classes

Implicit member declarations

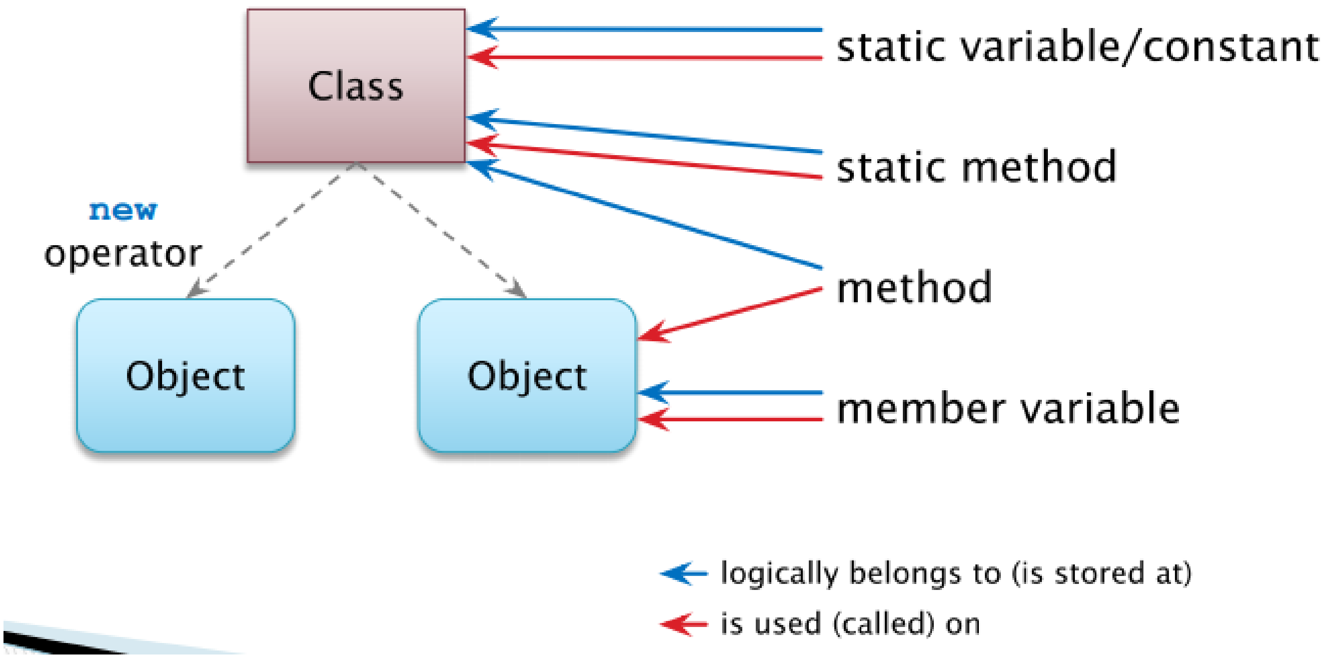
The members can be oterated over - object treated as an array.

```


class Foo {
    private $bar;
}
$foo = new Foo();
```

```
$foo->bar = 1;       // Error! 'bar' is private
$foo->barbar = 42;  // OK, new member is creat
```

`__constructor` VS `__destructor`

Member access



Cloning

Shallow - `$b = $a` Deep - explicit clone call - `$b = clone $a`

Internals and practices

Verify (input) data

ASAP from: `$_GET`, `$_POST`, `$_COOKIE`

`filter_input(), filter_var()`

`$foo = filter_input(INPUT_GET, 'foo', FILTER_VALIDATE_INT, $options);`

Invalid Inputs

- Ostrich algorithm
- Attempt to fix (e.g., select a valid part)
- User error

Sanitize output

AL(ate)AP - before sending the response

- `htmlspecialchars()` – encoding for HTML

- `urlencode()` – encoding for URL
- DBMS-specific functions (`mysqli_escape_string()`)
    - Better yet, use prepared statements

Sanitization

URL Handling

- `http_build_query()` – construct URL query string
- `parse_url()`

Base64

- Encode (any) data into text-safe form (6-bits/char)
- `base64_encode()`, `base64_decode()` ` JSON
- `json_encode()`, `json_decode()`, `json_last_error()`
- Lists are arrays, collections are `stdClass` objects

File uploads

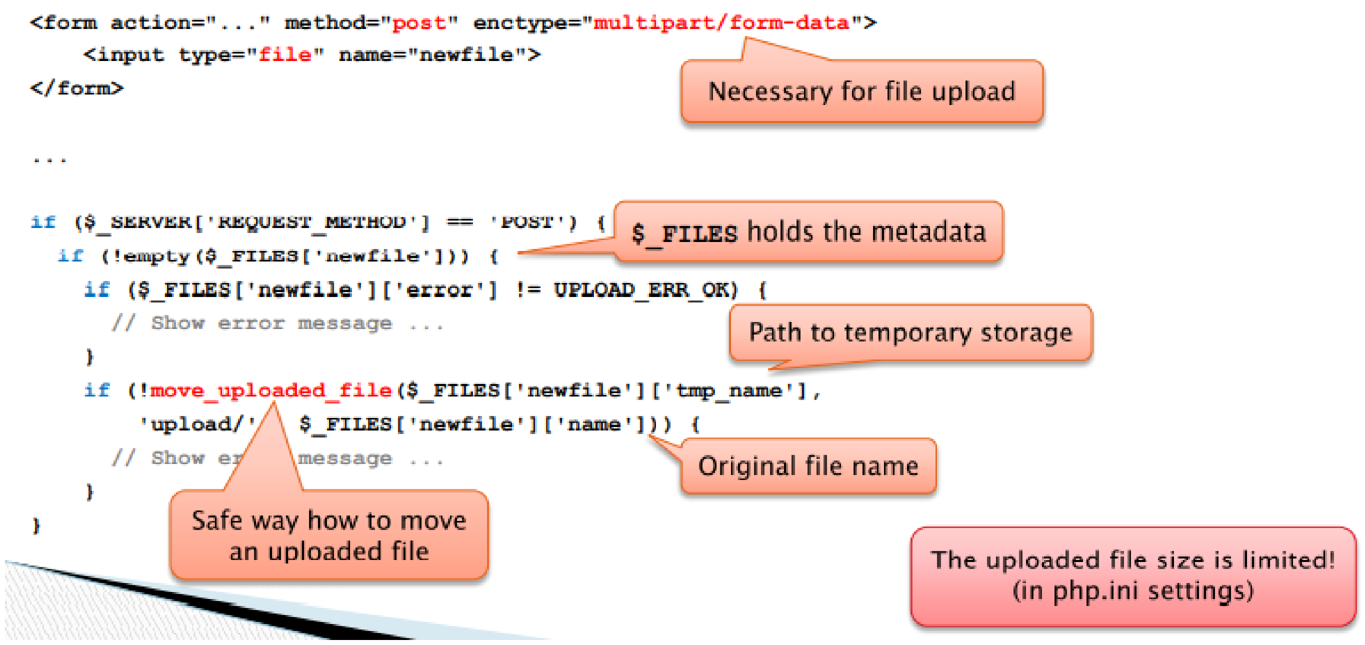
`<input type="file" name=... />`

Metadata in `$_FILES[name]`

- `tmp_name`
- `error` (`UPLOAD_ERR_OK`)
- `name`, `type`, `size`

Other:

- `is_uploaded_file()` – verification
- `move_uploaded_file()` – a safe way to move files



```
<form action="..." method="post" enctype="multipart/form-data">
    <input type="file" name="newfile">
</form>

...

if ($_SERVER['REQUEST_METHOD'] == 'POST') {
  if (!empty($_FILES['newfile'])) {
    if ($_FILES['newfile']['error'] != UPLOAD_ERR_OK) {
      // Show error message ...
    }
    if (!move_uploaded_file($_FILES['newfile']['tmp_name'],
        'upload/'   $_FILES['newfile']['name'])) {
      // Show er    message ...
    }
}
```

Necessary for file upload
$_FILES holds the metadata
Path to temporary storage
Original file name
Safe way how to move an uploaded file
The uploaded file size is limited! (in php.ini settings)

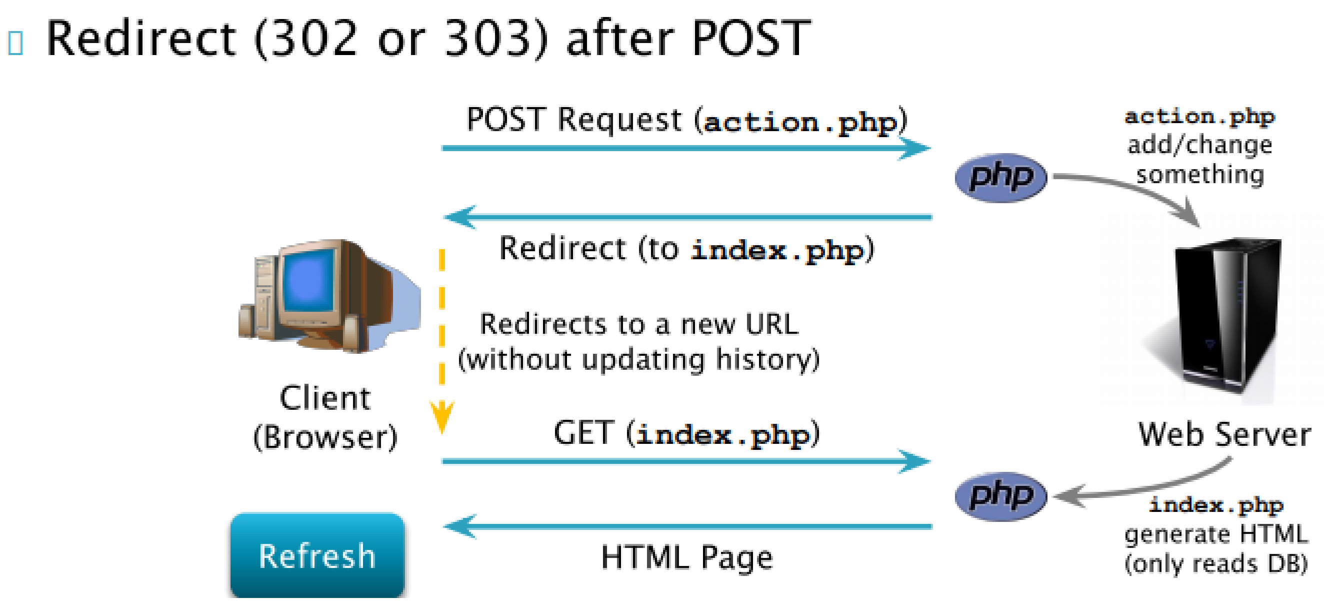
Raw request body

Access to Request Body Data

- In case the data are sent in special format (e.g., JSON)
- For other HTTP methods (e.g., PUT)
- Read-only stream `php://input`
  - `$body = file_get_contents('php://input');`
- There are other streams worth mentioning
  - `php://output`
  - `php://stdin`, `php://stdout`, `php://stderr`
  - `php://memory`, `php://temp`

Post processing

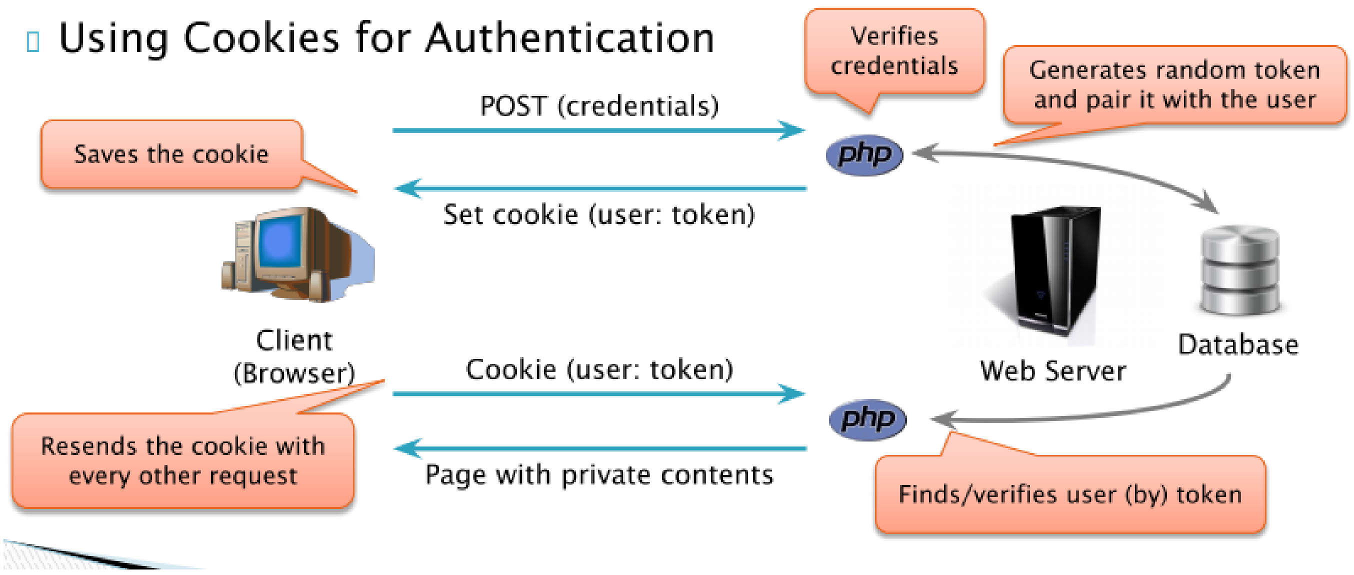
- Redirect Mechanism in HTTP
  - 3xx response code
  - 301 Moved Permanently
  - 302 Found (originally named Moved Temporarily)
  - 303 See Other
- Additional header `'Location'` has the new URL
- Browser must try to load the new URL (using GET method)
- Loops in redirections are detected Creating Redirect in PHP
- `header("Location: my-new-url");`
- Automatically changes the response code (to 302)


Redirect (302 or 303) after POST
POST Request (action.php)
php
action.php add/change something
Redirect (to index.php)
Redirects to a new URL (without updating history)
Client (Browser)
Web Server
GET (index.php)
php
index.php generate HTML (only reads DB)
Refresh
HTML Page

Session managment

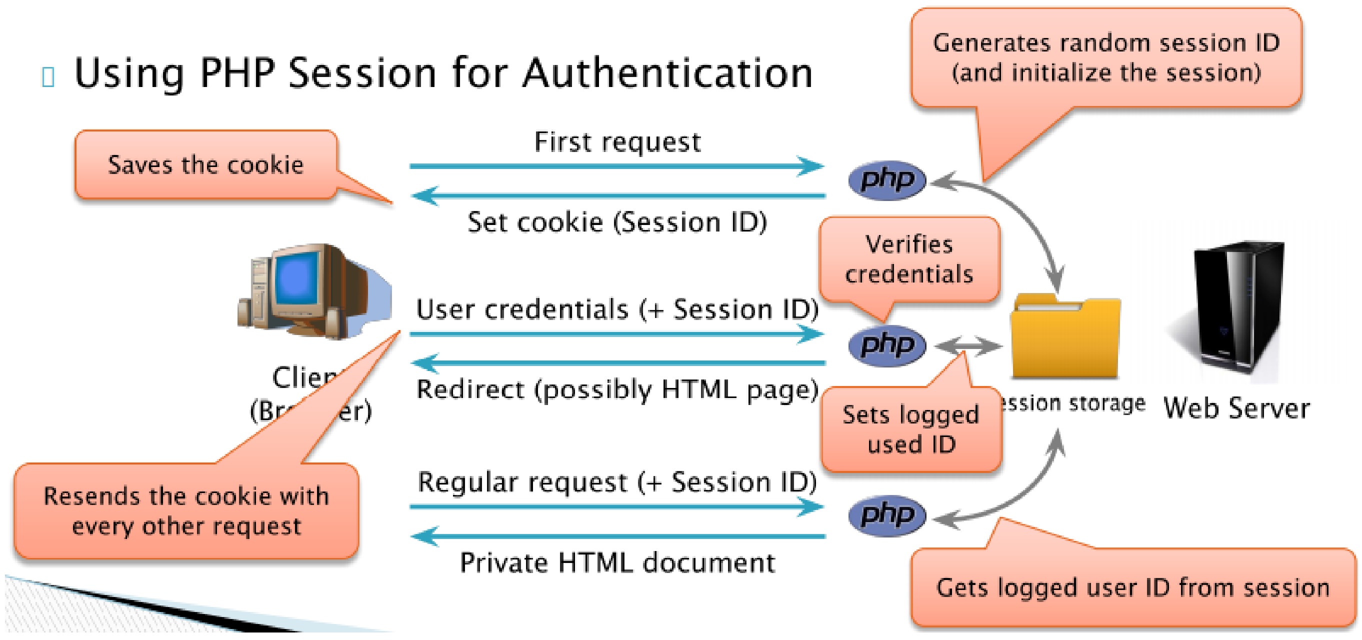
Cookies

- A way to deal with stateless nature of the HTTP
- Key-value pairs (of strings) stored in the web browser
    - Set by special HTTP response header
    - Automatically re-sent in headers with every request
    - Each page (domain) has it own set of cookies
- Cookies in PHP
    - Cookies are set/modified/removed by setcookie()
        - The function modifies HTTP response headers
    - Cookies sent by browser are loaded to $_COOKIE[]


Using Cookies for Authentication
Verifies credentials
Generates random token and pair it with the user
POST (credentials)
Saves the cookie
Set cookie (user: token)
Client (Browser)
Web Server
Database
Cookie (user: token)
Resends the cookie with every other request
Page with private contents
Finds/verifies user (by) token
php
php

PHP Session API

- Simple call to `session_start()` method
- Checks `$_COOKIE` and `$_GET` arrays for `PHPSESSID` variable which should have the ID
- If the variable is missing, new session is started
    - And a cookie with the new ID is set (if php.ini says so)
- Accessing Session Data
    - In the $_SESSION global array
        - Automatically loaded when the session is opened and serialized (saved) at the end of the script
    - It can be read and written (incl. unset() on items)


Using PHP Session for Authentication
Generates random session ID (and initialize the session)
Saves the cookie
First request
Set cookie (Session ID)
Verifies credentials
User credentials (+ Session ID)
Redirect (possibly HTML page)
Client (Browser)
Sets logged used ID
Session storage
Web Server
Resends the cookie with every other request
Regular request (+ Session ID)
Private HTML document
Gets logged user ID from session
php

Security Tokens

- Can be generated/verified only at server
- Has public payload that holds important data
  - E.g., user identity, expiration time, ...
- Digitally signed using crypto hash functions payload:salt:hash(payload:salt:secret)
- Stored only at client side (unlike session IDs)
  - But they can be stolen the same
  - Complicated invalidation
- See JSON Web Tokens (JWT) for example

Databases MySQL

`mysql` API is deprecated (as of PHP 5.5) ===> MySQL Improved (`mysqli`) API

- Dual object/procedural interface
  - Procedural interface is similar to original (deprecated) API
- Advanced connectivity features
  - Persistent connections, compression, encryption
- Directly supports transactions

MySQL Native Driver (`mysqlnd`) extension

- More direct access to MySQL server
- Additional features (e.g., asynchronous queries)

MySQLi Procedural API

```
// Establishing connection with MySQL server
$mysqli = mysqli_connect("server", "login",
                         "password", "db_name");

// Performing queries
```

```
$res = $mysqli->query("SQL …");

// Terminating connection
$mysqli->close();

// Safe way to include strings in SQL query
mysqli_real_escape_string($mysqli, $str);
```

Quering

- mysqli::query() result depends on the query type
    - On failure always returns false
- Modification queries return true on success
- Data queries (SELECT, ...) return mysqli_result obj

```
mysqli_result::fetch_assoc()
mysqli_result::fetch_object()
mysqli_result::fetch_all($format)
mysqli_result::fetch_fields()
mysqli_result::num_rows()
mysqli_result::free_result()
```

Prepared Statements

Prepare new MySQL statement

- `$stmt = mysqli::stmt_init(); mysqli_stmt::prepare("SELECT ...");`

Binding parameters (by positional placeholders)

- `mysqli_stmt::bind_param($types, $var1, …);`
- Types string – one char ~ one parameter

Execute and get result object

- `mysqli_stmt::execute();`
- `$res = mysqli_stmt::get_result();`

Examples

```
$mysqli = mysqli_connect("localhost", "login", "passwd", "dbname");
if (!$mysqli) ... // handle connection failure
$mysqli->set_charset("utf8");

$stmt = new mysqli_stmt($mysqli, 'SELECT * FROM lectures WHERE student_group =
?');
```

```
$studentGroup = '3rdyears';
$stmt->bind_param("s", $studentGroup);
$stmt->execute();
$res = $stmt->get_result();

while (($lecture = $res->fetch_object()) !== null) {
    echo "$lecture->id: $lecture->name";
}

$mysqli->close();
```

Frameworks

- **Symfony** – one of the most popular
- Laravel – one of the most popular
- **Slim** - micro-framework
- **Nette** – developed in Czechia (large Czech community)
- Zend – one of the oldest (a bit outdated)
- CodeIgniter
- Yii 2
- Phalcon
- CakePHP
- ...

Best practices and design patterns

SWING practices

- Analysis
  - Gathering/anticipating user requirements
  - Pay extra attention to scaling problems
- Development
  - Use appropriate scope
    - Trivial custom PHP for trivial applications, robust frameworks and design patterns for complex applications
- Testing
  - User/Application Testing (e.g., Selenium)
  - Unit testing (e.g., PHPUnit)
  - Continuous Integration (e.g., Travis CI)

Front-controller

- Application has a single point of entry (index.php)
  - All requests are directed to this script (bootstrap)
    - E.g., using mod_rewrite in Apache configuration
- Bootstrap script ensures routing and dispatching
  - Routing – selection of target class (routine, method, ...)
  - Dispatching – invocation of target (loading script, ...)

        - Different handling for GET and POST (PUT, DELETE, ...) requests

Advantages

- More secure (only one gate to fortify)
- Less error-prone for programmers

Examples

Redirecting everything to bootstrap (possibly with some URL rewriting)

- Apache .htaccess file

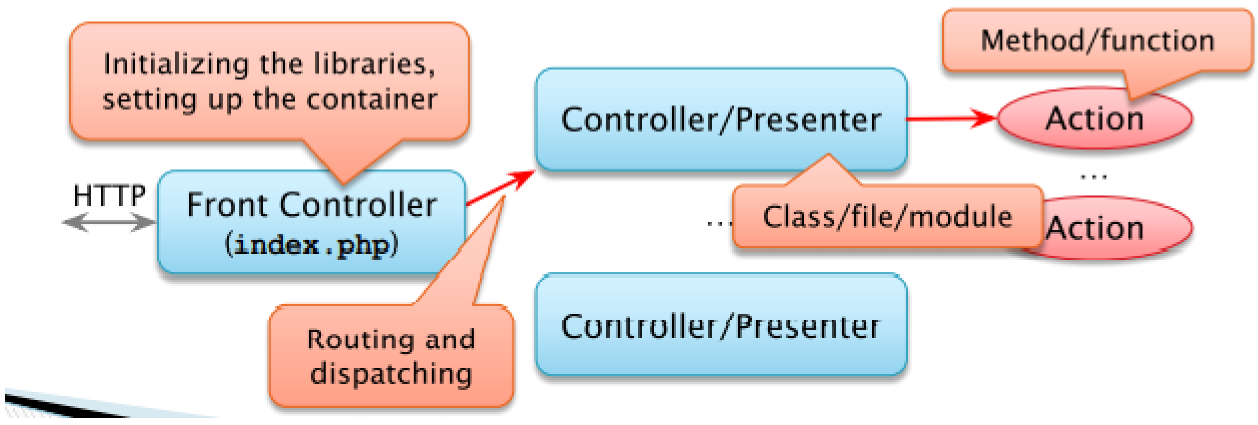
Imperative VS Declarative

```
switch ($_GET['page']) {
    case 'home':
        require 'home.php';
        break;
    case 'settings':
        require 'settings.php';
        break;
    ...
}
```

VS

```
$pages = [
    'home'     => 'home.php',
    'settings' => 'settings.php',
    ...
];
$page = $_GET['page'];
if (isset($pages[$page])) {
    require $pages[$page];
}
```

Larger example:



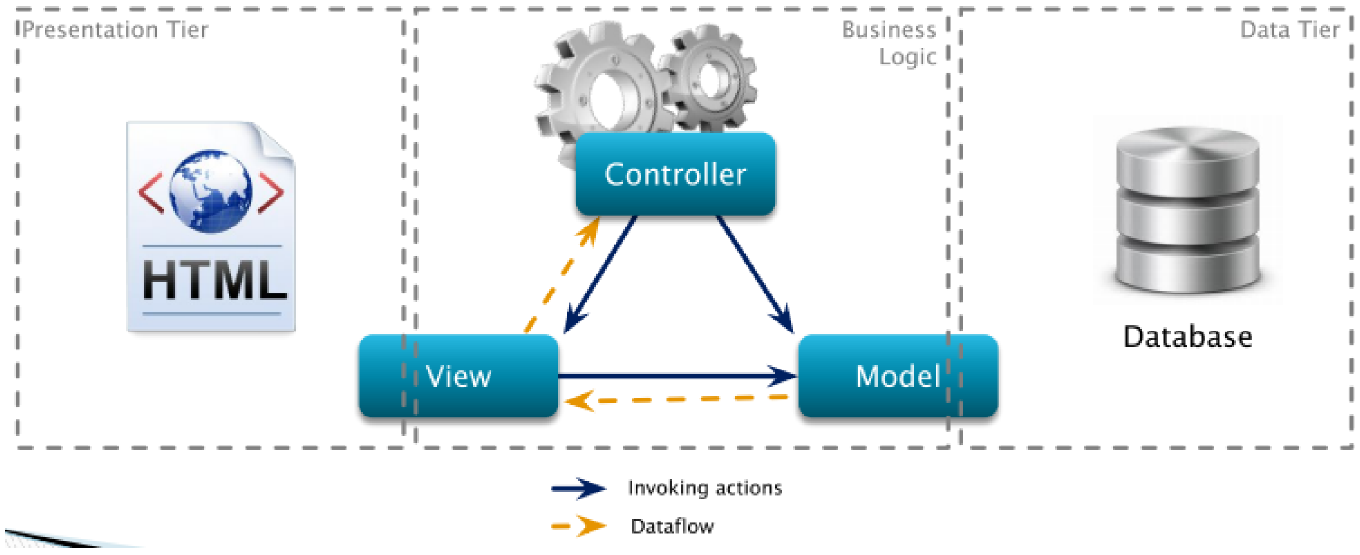
```
class Router {
    public function dispatch() {
        $page = empty($_GET['page']) ? $this->default : trim($_GET['page']);
        $controller = $this->container->getByName($page . 'Controller');
        if (!$controller) throw new Exception("Unknown page '$page'.");

        $reqMethod = strtolower($_SERVER['REQUEST_METHOD']);
        $action = empty($_GET['action']) ? '' :
ucfirst(strtolower(trim($_GET['action'])));
        $method = $reqMethod . $action . 'Action';
        if (!method_exists($controller, $method)) throw new Exception("...");

        if ($reqMethod === 'post')
            $controller->$method($_POST, $_GET);
        else
            $controller->$method($_GET);
        }
    }
}
```

MVC (Model-View-Vontroller)

A guideline how to divide code and responsibility

Basis for many frameworks

- Model
  - Uniform data API for the application
  - Communicates with DB/file storage/...
- View
  - Provides user interface (HTML rendering)
- Controller
  - Process requests (using view and model)
  - Business logic



View

- User interface, data presentation
- Typically responsible for generating HTML
- Automatic sanitization of presented data (<,> chars)
- Translations for multilingual applications
- Templates
  - Mechanisms that separate HTML coding from application programming
  - Allow implementing View features (mentioned above) in declarative (instead of imperative) manner
  - Idea of Templates
    - Separate HTML (CSS, ...) code from PHP scripts
    - Division of work (HTML coders vs. PHP programmers)
  - Template Systems
    - PHP-based
      - Template is also a PHP script
      - PHP-template only includes data into the HTML
    - Text-based
      - Special tags in HTML
        - {{tag_name}}, <%tag_name%>
      - Typically compiled into PHP-base templates

Latte templates example

```
<h1 n:block=title>Latte Example</h1>

<ul n:if="$items">
    <li n:foreach="$items as $item">{$item|capitalize}</li>
</ul>

{if ($user)}
<h2>User {$user->login}</h2>
Name: {$user->name}
```

```
Home page: <a n:href="$user->homepage">{$user->homepage}</a>
{/if}
```

Model

Implementing Data Models

- Direct SQL writing is inconvenient
    - Better to use some data abstraction layer
- **Object-relational Mapping** (ORM)
    - Tables are mapped to classes or singleton objects (called repositories)
    - Rows are mapped to objects (constructed by repositories)
    - The corresponding code (classes) has to be generated from the database schema (or vice versa)
        - In typical case, the schema is generated from code (classes)
        - Allows migration handling – ORM framework generate SQL alter table commands by comparing actual state of code and the - schema

Doctrine Example

- uses anotations

```
/** @Entity @Table(name="subjects") **/
class Lecture
{
    /** @Id @Column(type="integer") @GeneratedValue **/
    protected $id;

    /** @Column(type="string") **/
    protected $fullname;

    /** @ManyToOne(targetEntity="User", inversedBy="teach_lectures") **/
    protected $teacher;
    ...
    public function getDescriptionString() { ... }
    public function getStudents() { ... }
}
```

```
$entityManager = EntityManager::create($conn, $config);
$subj = $entityManager->find('Lecture', (int)$id);
$subj->setName('Web Applications');
$entityManager->flush();

$subjs = $entityManager->getRepository('Lecture')
    ->findBy([ 'programme' => 'I2' ]);
foreach ($subjs as $subj) {
    echo $subj->getDescriptionString();
    foreach ($subj->getStudents() as $student) {
        ...
    }
}
```

NotORM (by Jakub Vrána) Example

(Implementing Data Models)

- Keeping classes and DB schema in sync is very tedious in ORM systems
- Another approach is to use universal object mapping using dynamic features of PHP

```
$users = $db->users()
    ->select("id, login, name")
    ->where("active", true)
    ->order("name");
foreach ($users as $id => $user)
    echo $user["name"], "\n";
```

Controller

- Integrates business (application) logic
- Issues commands to view and model
- Process user requests
  - Requests for displaying content (typically GET request)
  - Requests for modifying app. status (typically POST req.)
- Typically implements other design patterns
  - Front controller, command, ...

MVC VS MVP

- Alternative – Model-View-Presenter
  - Slightly more advanced form of MVC
  - View is more separated and does not access model directly

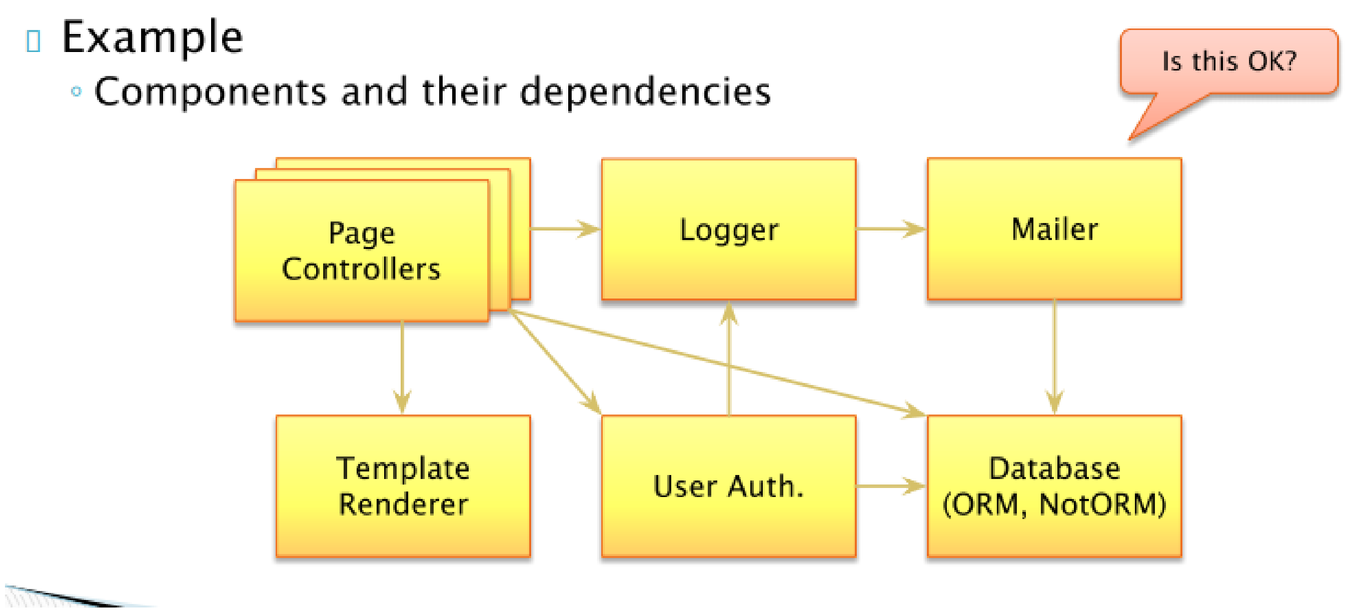
Example

```
class EditPresenter extends BasePresenter
{
    ...
    public function actionShowEditForm(string $id)
    {
        $object = $this->model->get($id);
        if ($object !== null) {
            $this->view->setArg('id', $id);
            $this->view->setArg('editedObject', $object);
        }
```

```
            $this->view->render();
        }
        ...
    }
```

Component-based Development

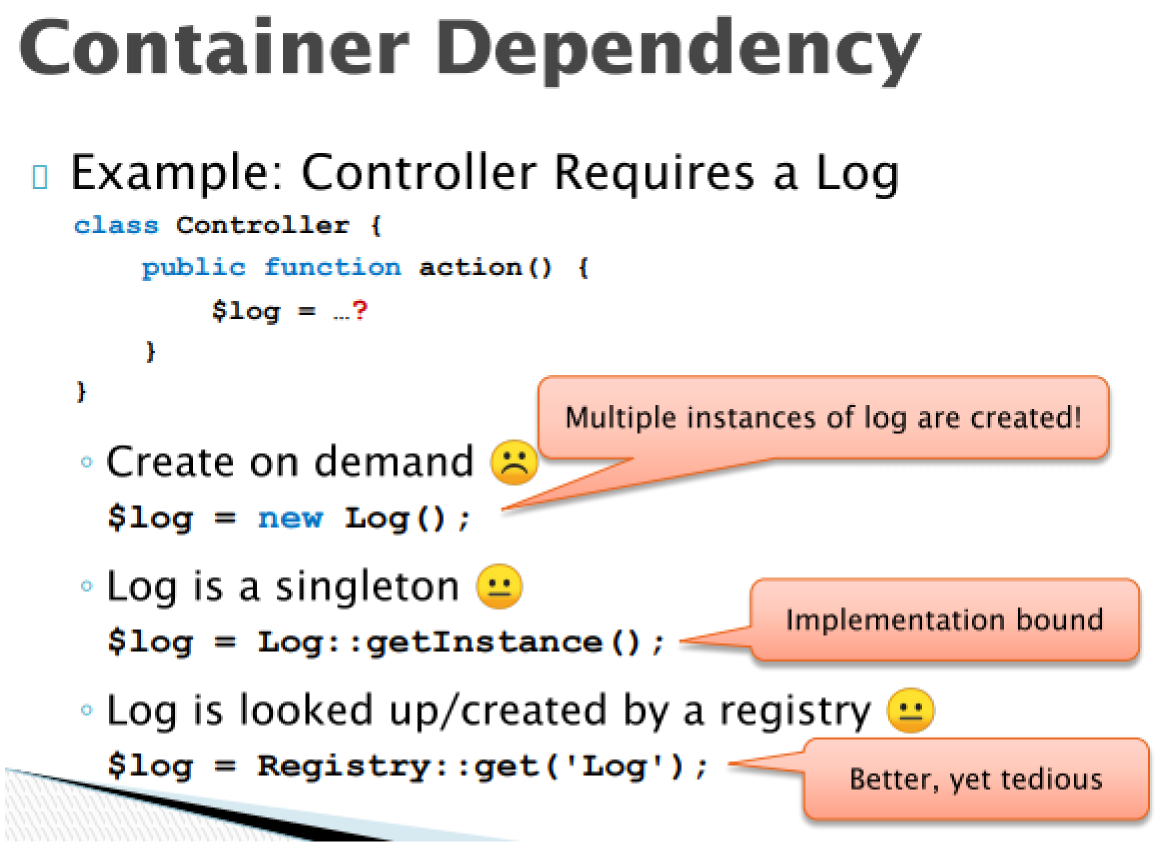
- Modern applications use components to promote encapsulation and separation of concerns
  - Component – a software module that provides some functionality through a well defined interface
    - Typically a class that implements an interface (in the code terminology)
    - Possibly a façade for a small set of classes
  - Component may depend on other components
    - Typically declares a list of (code) interfaces
    - Dependencies must be satisfied by providing components that implement given interfaces (allows some level of modularity)



- Example
  - Components and their dependencies

Component Management

- Creation and interlinking may be tedious
  - Who creates components?
  - When are the components created?
  - Where is the component configuration?
  - How do one component find other components it needs to use?
  - What about different implementations of the same component "types"?
  - ...



Container Dependency

- Example: Controller Requires a Log

```
class Controller {
    public function action() {
        $log = …?
    }
}
```

- Create on demand ☹
  `$log = new Log();`
- Log is a singleton 😐
  `$log = Log::getInstance();`
- Log is looked up/created by a registry 😐
  `$log = Registry::get('Log');`

Multiple instances of log are created!
Implementation bound
Better, yet tedious

====>

Dependency Injection

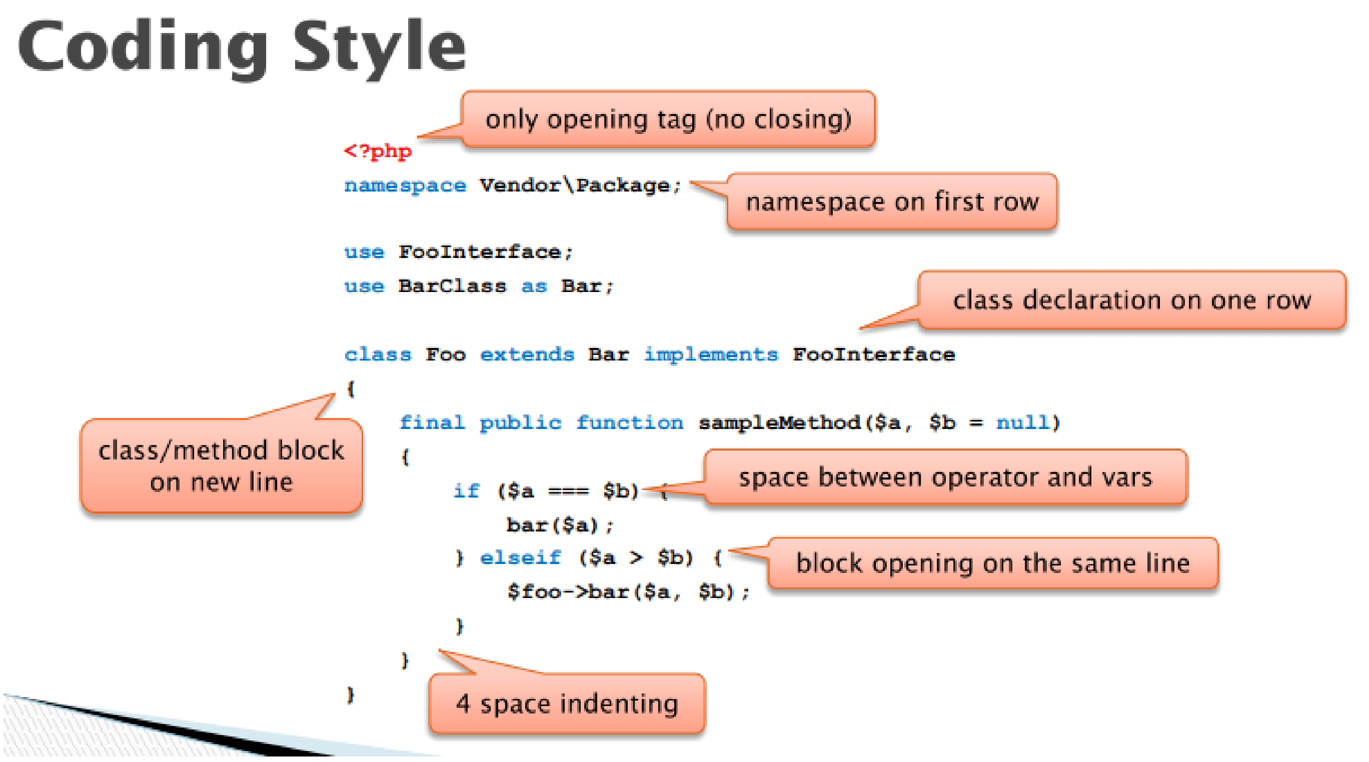
- Design pattern that implements inversion of control
  - Component is not responsible for seeking its own dependencies
  - Dependencies are injected externally (by the component manager)
- Declaring required dependencies
  - In configuration, by annotations, using reflection, ...
  - The problem of cyclic dependencies
    - DB component requires Log component to log errors
    - Log component requires DB component to save messages
- Central Component Manager
  - Responsible for creating and initializing components

```
/**
 * @component WelcomePage
 */
class WelcomePageController implements IController
{
    /** @inject IDatabase */
    public $db;

    /** @inject name="NewsService" */
    public $news;

    function __construct(ILog $log) { ... }
}
```

Standardization Recommendations

- Standardization beyond language specifications
- Improves cooperation, library designs, ...
- Accepted
  - PSR-1, PSR-2, PSR-12 Coding style guidelines
  - PSR-3 Logger interface
  - PSR-4 Autoloading (classes)
  - PSR-7 HTTP message interface
  - ...
- Drafts, pending reviews
  - Container interface, PHPDoc standard, ...

Coding style



Coding Style

```
<?php
namespace Vendor\Package;

use FooInterface;
use BarClass as Bar;

class Foo extends Bar implements FooInterface
{
    final public function sampleMethod($a, $b = null)
    {
        if ($a === $b) {
            bar($a);
        } elseif ($a > $b) {
            $foo->bar($a, $b);
        }
    }
}
```

only opening tag (no closing)
namespace on first row
class declaration on one row
class/method block on new line
space between operator and vars
block opening on the same line
4 space indenting

Single Page Applications

- The application logic runs in the browser
  - Provides more desktop-like user experience
  - HTTP requests are handled asynchronously (and covertly)
- Traditional browsing is typically discouraged
  - Handled internally by changing DOM dynamically
- Thin server architecture
  - Data storage, security verifications, via REST API

Disadvantages

- Application boot - loading and initialization time

- Less stable execution environment (many browser types)

REST (Representational State Transfer) API

- Server API which offers retrieval and manipulation with application resources in a HTTP-compliant way
  - Resources are identified by URIs
  - Operations are performed by HTTP requests
- REST formal constraints are
  - Client-server model
  - Stateless interface (no client context is cached at server)
  - Cacheable (response defines whether it can be cached)
  - Uniform interface
  - Layered system (proxies, servers may be replicated)

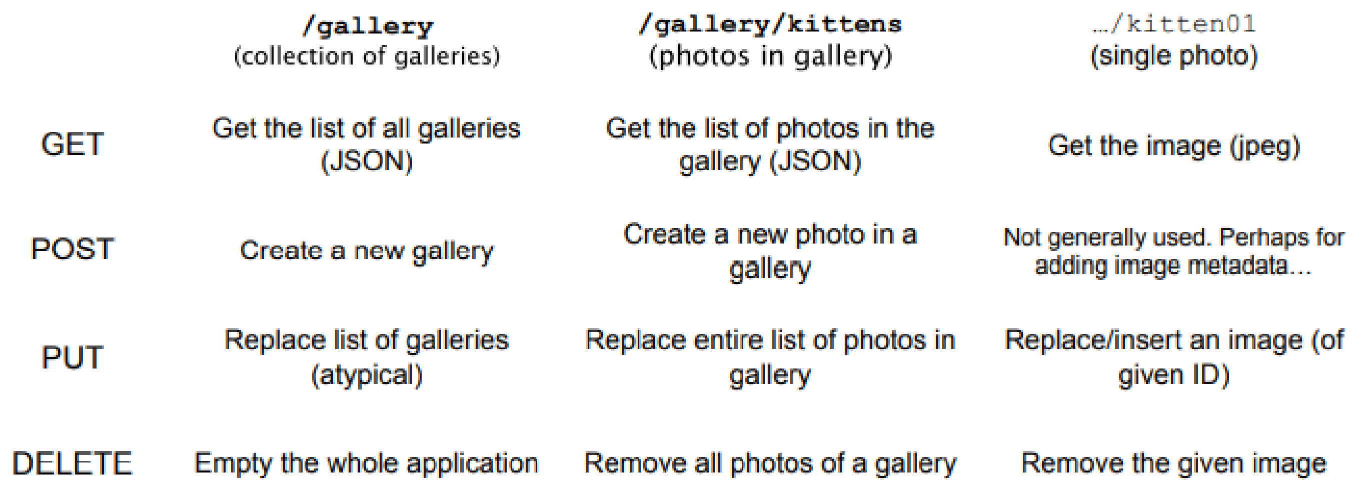
HTTP request methods reflect desired operations

- GET – retrieve the resource (nullipotent)
- POST – append new sub-entity in the resource
- PUT – insert/replace the resource (idempotent)
- DELETE – remove the resource (idempotent)

Example

API for photo gallery

- `/gallery` – collection of all galleries
- `/gallery/kittens` - photos in gallery with ID=kittens
- `/gallery/kittens/kitten01` – photo kitten01



	/gallery (collection of galleries)	**/gallery/kittens** (photos in gallery)	…/kitten01 (single photo)
GET	Get the list of all galleries (JSON)	Get the list of photos in the gallery (JSON)	Get the image (jpeg)
POST	Create a new gallery	Create a new photo in a gallery	Not generally used. Perhaps for adding image metadata…
PUT	Replace list of galleries (atypical)	Replace entire list of photos in gallery	Replace/insert an image (of given ID)
DELETE	Empty the whole application	Remove all photos of a gallery	Remove the given image

Javascript

Name debunk - not from Java.

ECMAScript

- Ecma International - Non-profit standards org.
  - Standardizes only the language

- We will cover ES v5.1, which is widely supported
- Important differences in ES v6 (Harmony)
- Current ES: v11 (ECMAScript2020) released this year

Scripting Languages

- JavaScript – ECMAScript adapted for web browser
- JScript – Microsoft variation on the JavaScript theme
- ActionScript – ECMAScript used in Adobe Flash

Values

Types

(`typeof`)

- number,
- string,
- boolean,
- object,
- function, and
- undefined

```
"5" + 4  // is "54" (string)
"5" * 4  // is  20  (number)
console.log(myObject) // .toString() invoked
```

Variables

Mnemonic holders for values

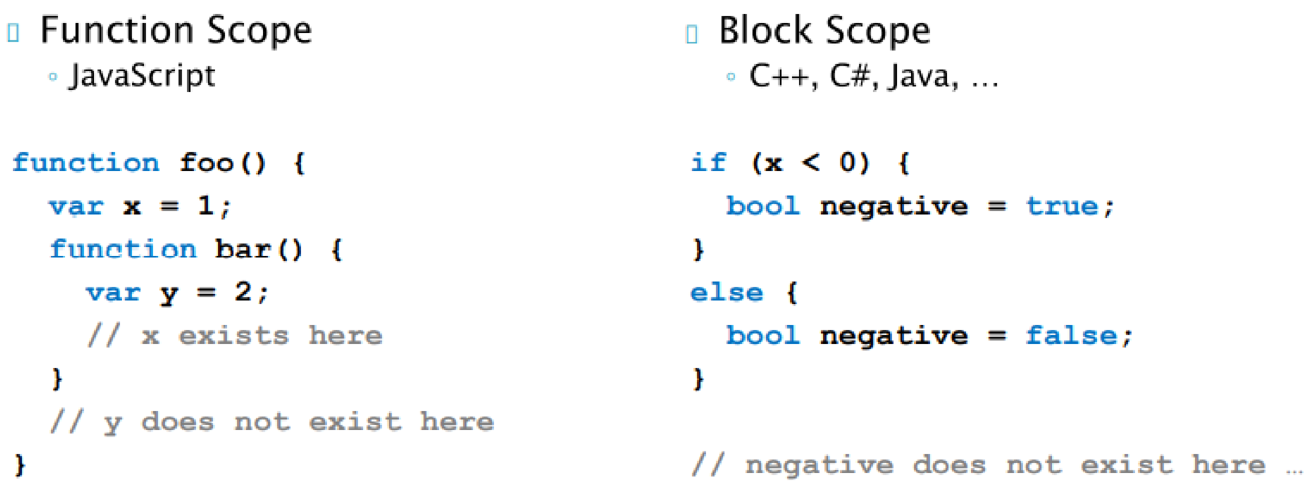
- Rather “attachments” to values than “memory boxes”
- No type defined (type is carried by the value)

Declared by var keyword

- `var x; var y = 1; var a, b, c;`

The declaration is affected by the current scope

- In global scope, the variables are assigned to the script environment (e.g., object window in the browser)
    - `var x = 1; (global)` and `window.x = 1;` are equivalent
- In a function, the variable belongs to the local scope (more details later)



- Function Scope
  - JavaScript

```
function foo() {
  var x = 1;
  function bar() {
    var y = 2;
    // x exists here
  }
  // y does not exist here
}
```

- Block Scope
  - C++, C#, Java, …

```
if (x < 0) {
  bool negative = true;
}
else {
  bool negative = false;
}

// negative does not exist here …
```

Functions

"callable object"

```
function foo(args) { body }
var foo = function(args) { body }
var foo = new Function(args, "body");
```

Objects

Objects are unordered name-value collections

All members are public

```
var myObject = {
    foo: 10,
    bar: function() {
        ...
    }
};
myObject.bar();
myObject.anotherFoo = 100;
delete myObject.foo;
```

Arrays

Creating Arrays

```
var arr = [ 1, 3, 19, 42 ];
var arr = new Array(1, 3, 19, 42);
var arr = new Array(length);
```

Accessing Elements

```
var arr = [ 'x', 'y', 'z' ];
console.log(arr[1]);
arr[2] = 'zzz';
arr[arr.length] = 'another one';
delete arr[1];
```

Methods

```
pop(), push(e1, …) // add/remove end of array
shift(), unshift(e1, …) // like pop/push at front
slice(begin, end) // get sub-array (range)
splice(idx, count, e1, …) // update sub-array
sort()
join(sep) // glue elements together into a string
indexOf(elem) // find element in array
forEach(fnc) // invoke a function for each element
filter(fnc) // return array filtered by a function
map(fnc) // generate elements by a map function
```

Strings

String Literals

- `var str1 = 'a string', str2 = "another string";`
- No difference between quotes and double quotes
- Operator + is used for concatenation
    - Beware that + is also used as numerical addition

String Object

- Strings can also be represented by a String object
    - Transparent conversions between both representations
        - `"str".length` // == 3

Methods

```
charAt(idx) // returns one character
concat(s1, …) // concatenate strings
indexOf(str) // finds a substring within a string
match(regexp) // test regular expression match
replace(old, new) // replace part of the string
slice(from, to) // return a substring
split(sep) // chop the string to array of tokens
toLowerCase() // return a new lower-cased string
trim() // remove leading and trailing whitespace
```

Client-side scripting

- Dynamic modifications of HTML and CSS
- Handling user actions within the browser
- Asynchronous communication with server

Challenges

Security

- The script is completely isolated from the computer
- It may interact only through the browser

Performance

- Limited due to properties of scripting languages and security measures imposed by the browser

Utilization

- User input processing and verification
- Background data retrieval and synchronization
- Generating graphics (SVG or with the canvas element)
- Single Page Applications (SPA)

Technologies

- JavaScript – dominating in current web applications
- VBScript – used in MSIE in the past
- 3rd party technologies (Flash, Silverlight, ...)

Embedding

Embedded Scripts

```
<script type="text/javascript">
    the JavaScript code
</script>
```

Linked Scripts

- `<script type="text/javascript" src="url"></script>`

Event handlers

- `<img src="url" onmouseover="code-handling-event">`

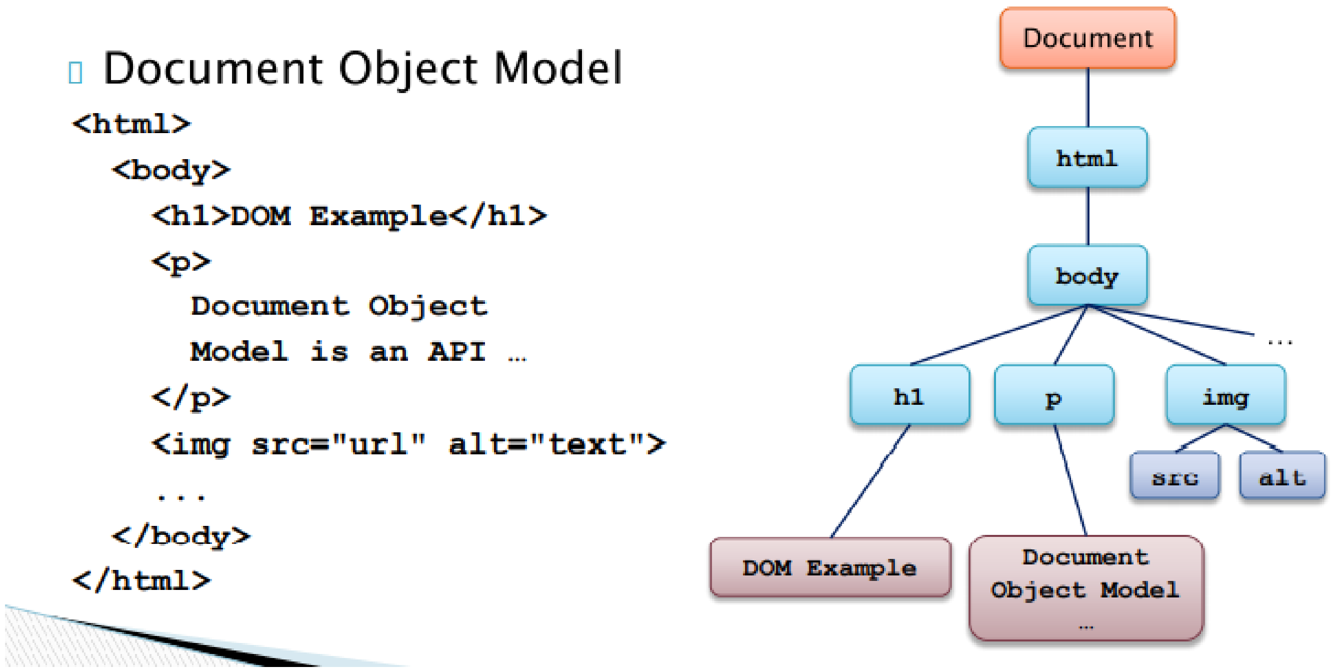
In web browser

Global object window

- API for current browser window/tab
- Presents the global context
- Encapsulates all prepared objects and APIs
  - window.document – DOM API for HTML document
  - window.location – Access/control current URL
  - window.history – Navigate through browser history
  - window.screen – Information about system screen
  - window.navigator – Information about the browser
  - ...
- Controls the pop-up message boxes

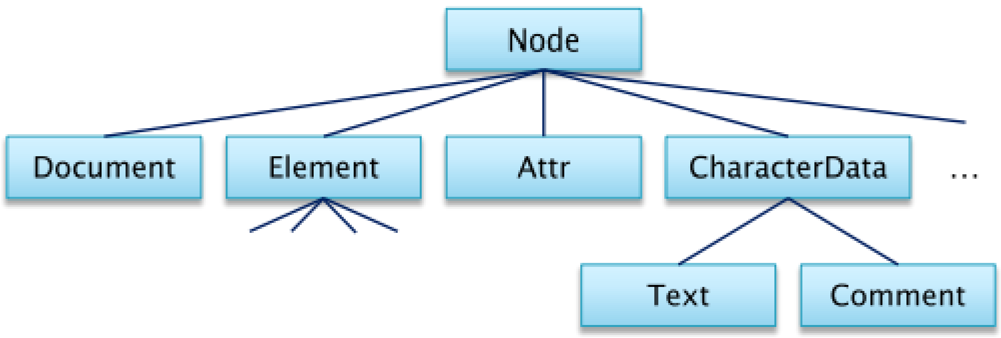
DOM (Document Object Model)

- Object model representing HTML/XML tree
- Class of each node corresponds with the node type
- Different nodes allow different methods



Document Object Model

```
<html>
  <body>
    <h1>DOM Example</h1>
    <p>
      Document Object
      Model is an API …
    </p>
    <img src="url" alt="text">
    ...
  </body>
</html>
```



Levels

Incremental standards for DOM issued by W3C

- Level 0
  - Various technologies before standardization
  - Sometimes also denoted DHTML (dynamic HTML)
- Level 1 – basic navigation and manipulation
- Level 2 – added namespaces, events, and CSS
- Level 3 – keyboard events, XPath, load and store
- Level 4 – being developed

Browsers support entire level 1 and most of 2 and 3

Traversing

- `Node.firstChild`, `Node.lastChild`
- `Node.childNodes`
- `Node.nextSibling`, `Node.previousSibling`
- `Node.parentNode`, `Node.parentElement`
- `Node.nodeName`, `Node.nodeValue`
- `Node.attributes` – relevant for elements only
- `Document.documentElement` – root element
- `Document.getElementsByTagName(tagName)`
- `Document.getElementById(id)`

Manipulation

- `Document.createElement()`, ...
- `Node.appendChild()`, `Node.insertBefore()`
- `Node.replaceChild()`, `Node.removeChild()`
- `Element.getAttribute()`, `Element.setAttribute()`
- `Element.removeAttribute()`
- `Node.cloneNode(deep)`

Extra

- `Node.innerHTML`, `Node.outerHTML`
- `Document.evaluate(xpath)`

DOM and CSS

- HTMLElement.style
  - Represent properties in style attribute
  - Properties are represented in CSS object model
    - `var hln = document.getElementById("headline");`
    - `hln.style.backgroundColor = '#ffeecc';`
  - Property names in model corresponds to names in CSS
    - Dashes are removed and following words are capitalized
- `Element.className`, `Element.classList`
- `Document.styleSheets[].cssRules[]`
  - `.selectorText` – string with CSS selector

    - `.style` – same as `Element.style`

Events

Events may be handled by callback functions

- Attached directly in HTML (only in special cases!)
    - `<button onclick="js code handling the event">`
- Or by Javascript code
    - `myButton.onclick = function(event) { ... }` or
    - `myButton.addEventListener('click', fnc, capture);`

The choice of the day – `addEventListener()`

- Allows multiple handlers on one event
- Works on any DOM element (not just visual elements)
- Allows early event capturing

Event object

Event is represented by an object implementing Event interface

- Special events may implement some other interface derived from `Event` (e.g., `MouseEvent`)

The object carries event information

- `Event.target`, `Event.currentTarget`
- `Event.bubbles`, `Event.cancelable`
- Event specific information (e.g., mouse coordinates)

The event propagation may be disrupted

- `Event.preventDefault()`
- `Event.stopPropagation()`

Window

User interaction

- `window.alert(msg)`, `window.confirm(msg)`
- `window.prompt(msg, defaultText)`

Important events

- `window.onload`
- `window.onresize`
- `window.onbeforeunload`, `window.onunload`

Timers

- `window.setTimeout(code, ms)`
- `window.setInterval(code, ms)`

- `window.clearTimeout()`, `window.clearInterval()`

Location

- Read/write value gets/sets URL in address bar
- `location.host`, `location.pathname`, ...
- `location.assign(url)`, `location.replace(url)`
- `location.reload()`

History

- Manipulate the browser history of navigation
- `history.length` – number of items in history
- `history.back()`, `history.forward()`
- `history.go(offset)` – move in history by offset

Details

Revision

JavaScript

- Weakly-typed, dynamic, C-like, object-oriented, prototyping, functional language Values vs variables
- Variable type is determined by the value Available data types
- number, string, boolean, object, function, and undefined Functions
- 1st class citizens (declare function = create value) Objects
- Dynamic name-value collections

Functions

```
var a1; // global scope (obj. window in browser)
function foo() {
    var a2; // local scope of foo()
    function innerFoo() {
        var a3; // local scope of innerFoo()
        function innerInnerFoo() {
            // I can see a1, a2, and a3 from here …
            a2 = a1;
        }
    }
}
```

Closure

```
function createAdder(x) {
    return function(y) {
        return x + y; // The Inner function can see variable x due to scoping
rules
```

```
    }
}

var add3 = createAdder(3); // When the inner function is created, the closure
captures value of x == 3
var add7 = createAdder(7); // New function have a new closure where x == 7

add3(10); // is 13
add7(10); // is 17
```

```
function bindFirst(fnc, x) { // “Universal” binding function
    return function(y) {
        return fnc(x, y);
    }
}

function add(x, y) { return x + y; }
function mul(x, y) { return x * y; }

var add3 = bindFirst(add, 3);
var mul3 = bindFirst(mul, 3);

add3(14);  // is 17
mul3(14);  // is 42
```

Objects

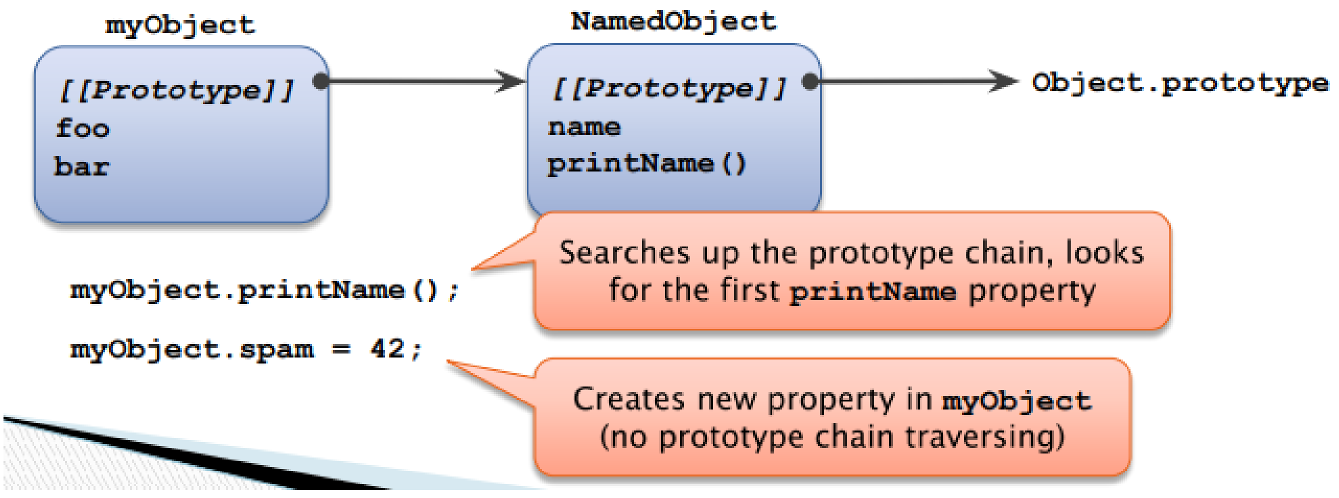
Revision

- Objects are unordered name-value collections
- All members are public

```
var myObject = { // Creates simple object with two members (foo and bar), where
foo is a Number and bar is Function (i.e., in some sense a method).
    foo: 10,
    bar: function() {
        ...
    }
};
myObject.bar();
myObject.anotherFoo = 100; // Members may be added dynamically.
```

Classes

No real classes, PROTOTYPES

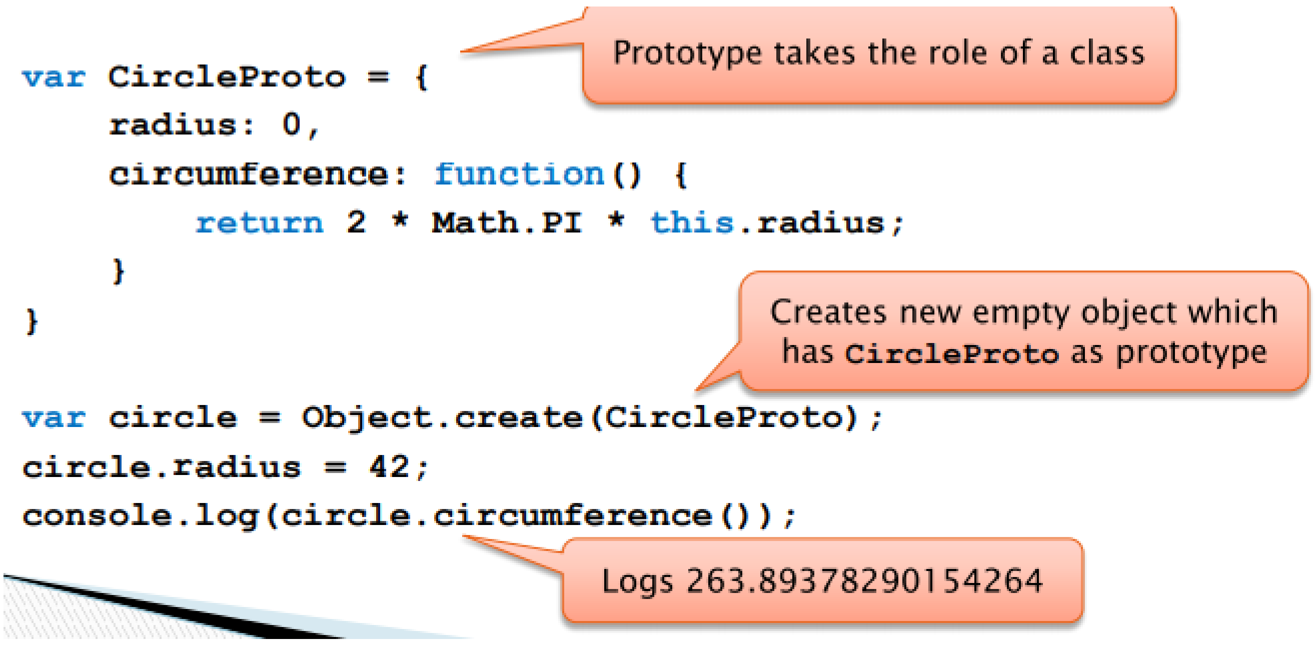


```
myObject.printName();
```

Searches up the prototype chain, looks for the first **printName** property

```
myObject.spam = 42;
```

Creates new property in **myObject** (no prototype chain traversing)



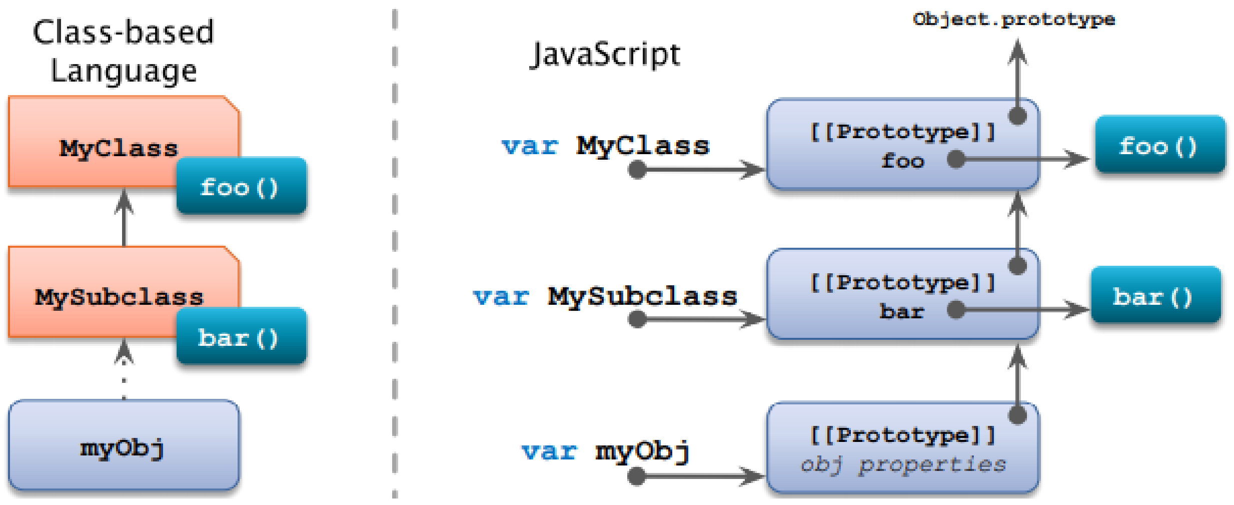
```
var CircleProto = {
    radius: 0,
    circumference: function() {
        return 2 * Math.PI * this.radius;
    }
}

var circle = Object.create(CircleProto);
circle.radius = 42;
console.log(circle.circumference());
```

Prototype takes the role of a class

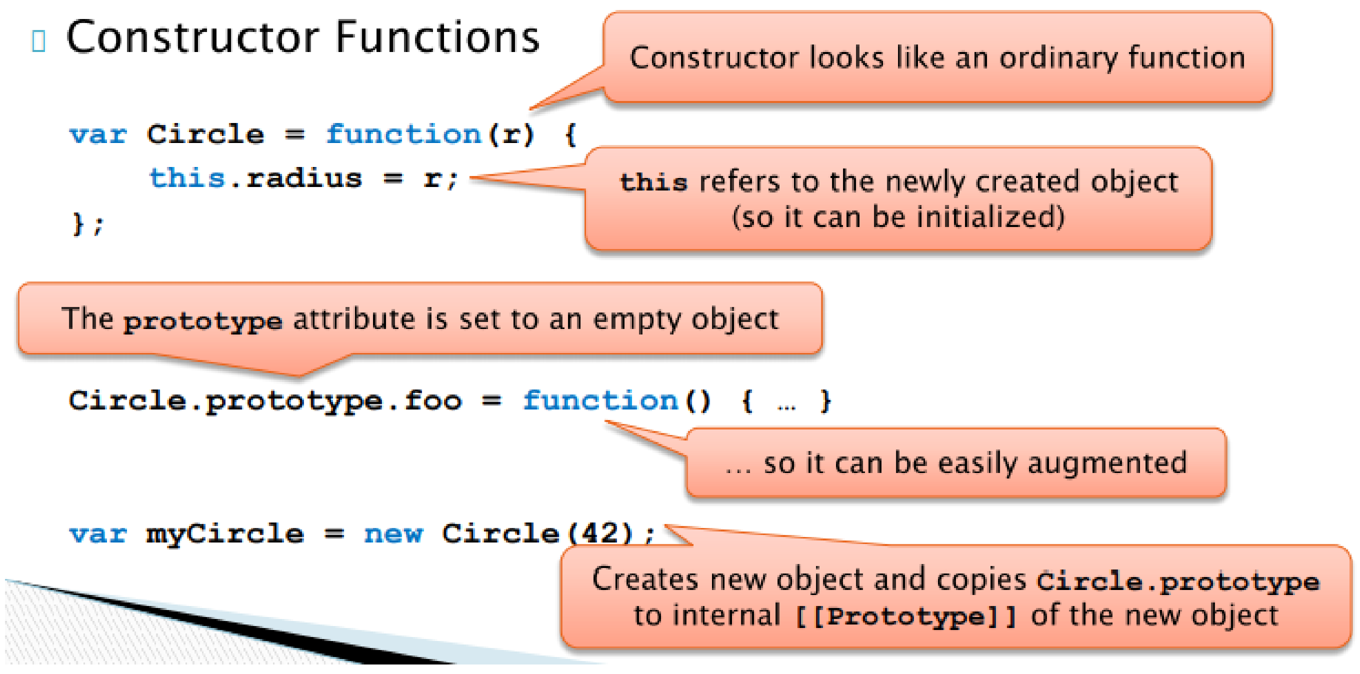
Creates new empty object which has **CircleProto** as prototype

Logs 263.89378290154264

Classes vs Prototypes



Ctors



Constructor Functions

```
var Circle = function(r) {
    this.radius = r;
};
```

Constructor looks like an ordinary function

this refers to the newly created object (so it can be initialized)

The prototype attribute is set to an empty object

```
Circle.prototype.foo = function() { … }
```

… so it can be easily augmented

```
var myCircle = new Circle(42);
```

Creates new object and copies Circle.prototype to internal [[Prototype]] of the new object

- Constructor Object
  - `var o = new Object(value);`
  - All objects are descendants of an Object
  - Interesting properties
    - `create(proto, [props])` – create new object
    - `getOwnPropertyNames(obj)` – return array of property names that are native to obj
    - `getPrototypeOf(obj)` – get prototype object of obj
    - `preventExtensions(obj)` – prevent properties from being added to obj object
    - `seal(obj)` – prevent adding/removing properties
    - `freeze(obj)` – prevent any property modifications

JS built-ins

- General-purpose Constructors

  - Wrappers for basic types
    - Number, String, Boolean, Object, Function
    - Basic primitives (string, boolean, and number) are automatically converted to their respective wrappers
      - E.g., when a method is invoked upon them
    - Provide additional functionality
  - Array – object wrapper for “traditional” arrays
  - Date – time and date information
  - Iterator – implements iterator pattern
  - RegExp – regular expression

- Non-constructor Functions

  - `encodeURI(str)` – encode string for URI
  - `decodeURI(str)` – decode URI to normal string
  - `parseInt(str, rdx)` – parse textual representation of an integer of given radix

  - `parseFloat(str)` – parse textual representation of a floating point number
  - `encode(str)` – encode non-ascii chars
  - `decode(str)` – reverse function to `encode()`
  - `eval(str)` – to be reviewed later...

ECMAScript 6

Class

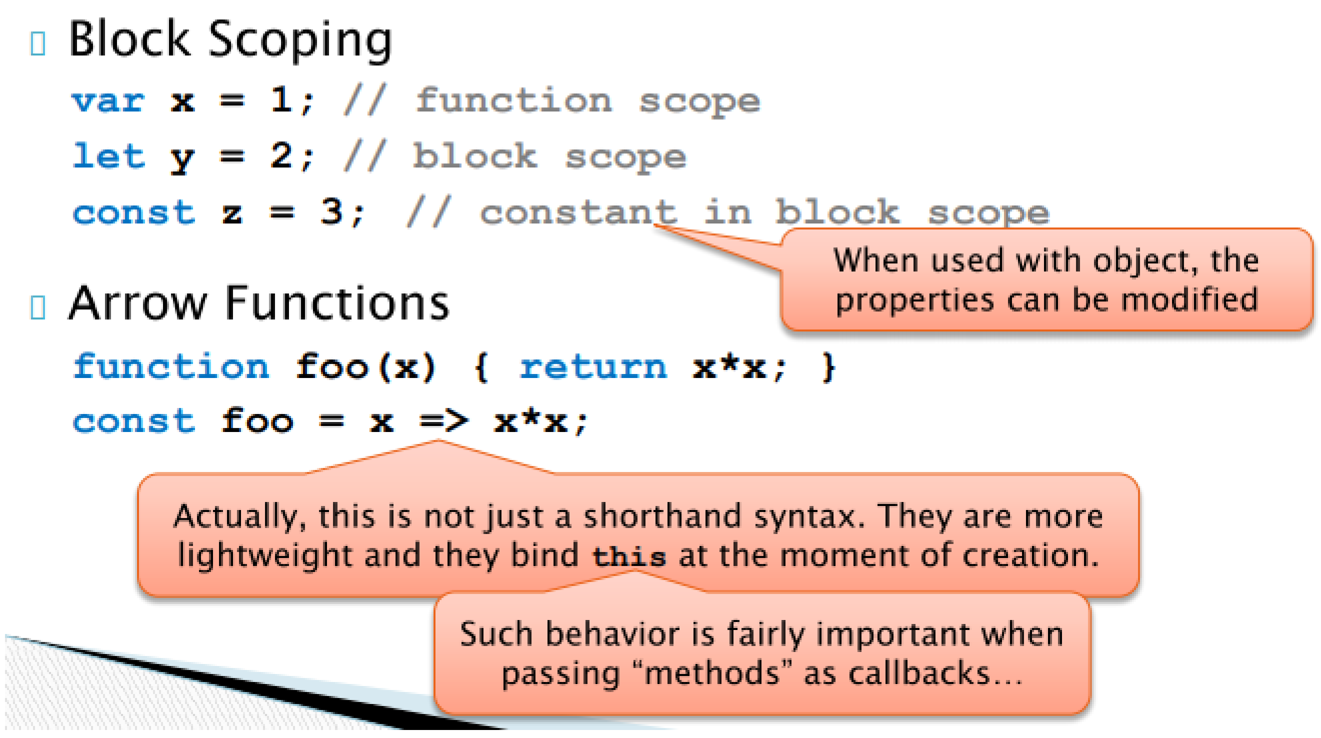
```
class Circle extends GeometricShape
{
    constructor (x, y, r) {
        super(x, y);
        this.r = r;
    }
    getArea () {
        return Math.PI * r * r;
    }
}

const circle = new Circle(10, 20, 5)
```

Modules

Way to export/import modular values without polluting the global context (avoiding name collisions)

```
// mylib.js
export function explain() { return "because 6 x 9"; };
export var universalConst = 42;

// an application using mylib.js
import * as mylib from "mylib";
console.log(mylib.universalConst + " " + mylib.explain());

// another application using mylib
import { explain, universalConst } from "mylib";
console.log(universalConst + " " + explain()
```

Scopes and arrow functions



Block Scoping

```
var x = 1; // function scope
let y = 2; // block scope
const z = 3;  // constant in block scope
```

When used with object, the properties can be modified

Arrow Functions

```
function foo(x) { return x*x; }
const foo = x => x*x;
```

Actually, this is not just a shorthand syntax. They are more lightweight and they bind **this** at the moment of creation.

Such behavior is fairly important when passing “methods” as callbacks…

Variables and arguments

Default parameter values

- `function inc(val, by = 1) { return val + by; }`

Aggregation of remaining arguments

- `function merge(al, a2, ...restArrays) {}`

Spread collection elements as arguments

```
var coords = [ 1, 2 ,3 ];
point.moveBy(...coords);   // moveBy(1, 2, 3);
var str = "bar";
var chars = [ "f", "o", "o", ...str ];   // b, a, r
```

Array matching

```
var list = [ 1, 2, 3 ];
var [ x, y, z ] = list;  // var x=1, y=2, z=3
[ z, x, y ] = [ x, y, z ];   // rotate values x,y,z
var [ head, ...rest ] = list; // decapitation
var a = [ ...arr1, ...arr2 ]; // array concatenation
```

Object matching

```
var { x, y, z } = get3Dpoint();
var { x: y, y: x, attrs: { depth: z } } = get2Dpoint();
```

Context argument matching

```
function avgFirst2([a, b]) { return (a + b) / 2; }
function distanceTo({x, y, z = 1}) { … }
```

New structures

Set – a collection of unique items

```
const s = new Set();
s.add("kitten").add("hippo").add("kitten");
s.size;            // === 3
s.has("hippo");    // === true
```

Map – a dictionary (key-value) structure

```
const m = new Map();
m.set("answer", 42);
m.set("correct", 54);
m.get("correct");  // === 54
m.size;            // === 2
```

Functional approach

Shift in Paradigm JavaScript is leaning steadily towards functional programming paradigm

```
const data = [ 1, 2, 3, 4, 5, 6 ];
for (let i = 0; i < data.length; ++i) {
    if (data[i] % 2 !== 0) continue;
    let x = data[i] * data[i];
    console.log(x);
}
```

```
const data = [ 1, 2, 3, 4, 5, 6 ];
data.filter(x => x % 2 === 0)
    .map(x => x * x)
    .forEach(x => console.log(x));
```

```
const traverse = node =>
  (typeof(node) === 'object'
    ? Array.isArray(node)
      ? node.reduce((acc, val) =>
          [...acc, ...traverse(val)], [])
      : [node, ...traverse(Object.values(node))]
    : [])
  .filter(({id, command, priority, dependencies}) =>
    id && command && priority !== undefined
      && dependencies);
```

Errors/Exceptions

- JavaScript is very error-prone language
- Error usually stops current JavaScript code
- Error handling is similar to exception catching:

```
try { ... secured code ... }
catch(err) { ... error handling ... }
finally { ... finalization code ... }
```

- Can be triggered manually
  - `throw something;`
- Regular errors are created by Error constructor
- Parameter message with human-readable description

Explicit Evaluation

- The `eval(code)` function

- The code is JavaScript code represented as string

- The code is interpreted and its last value is returned

- `eval("3+4"); // returns 7`

- The eval() should be avoided whenever possible

  - `eval("var res = obj." + propName);` is equivalent with `var res = obj[propName];`

- Functions as callbacks can be used in many places to avoid explicit `eval()` call

Client-side programming

UI

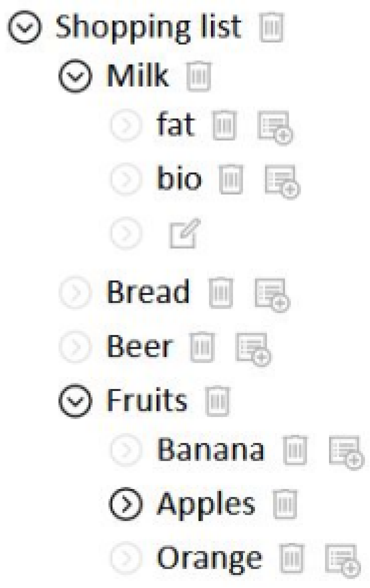
Web Application UI Expressed in HTML and CSS DOM is a data structure that holds part of application state State (data) synchronization issue (single truth)

Solving State Synchronization Issue The state is kept only in DOM Example: Collapsible list Nested item list Each item with sub-list is collapsible Collapsed/Expanded state is defined by a presence of a CSS class CSS class also hides the sub-list On-click event toggles the class Initial state can be encoded in HTML

```
<li>Shopping list
  <ul>
    <li class="collapsed">Milk
      <ul>...
```

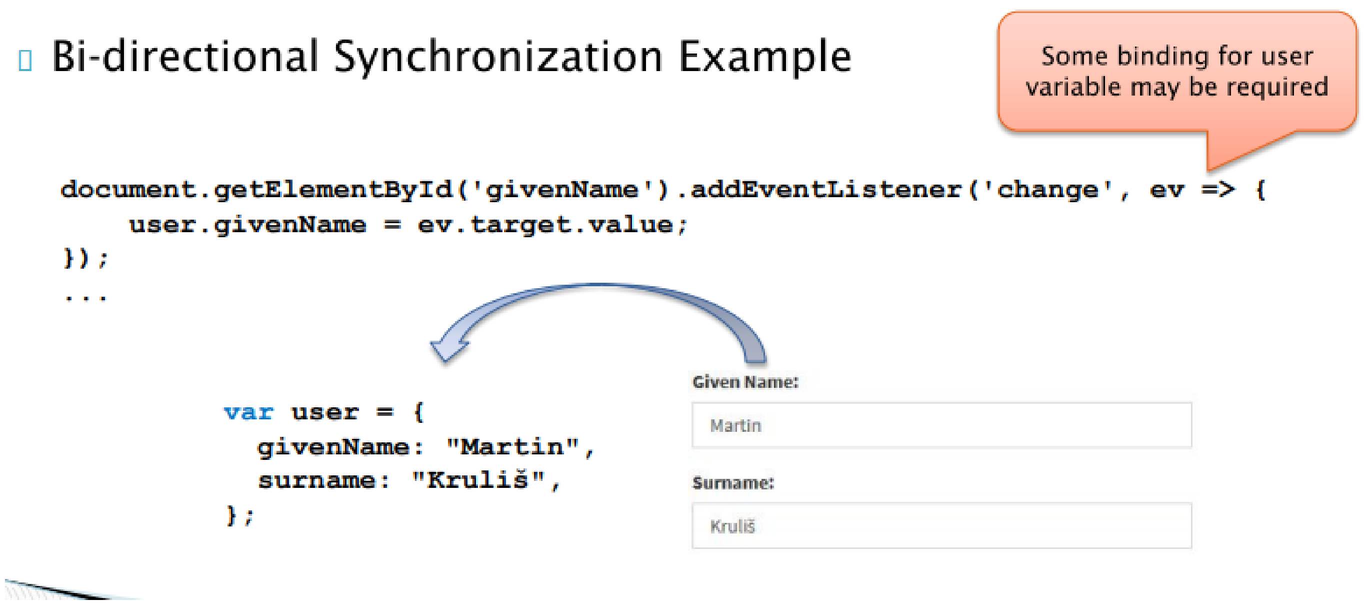
```
li.collapsed > ul { display: none; }
```

```
something.addEventListener(click, ev => {
  ev.target.classList.toggle('collapsed');
});
```



Bi-directional sync

- Solving State Synchronization Issue
  - Data are kept both in JS memory and in DOM
  - Bi-directional synchronization is established
    - Preferably automated
    - Connections are defined in declarative manner



Bi-directional Synchronization Example

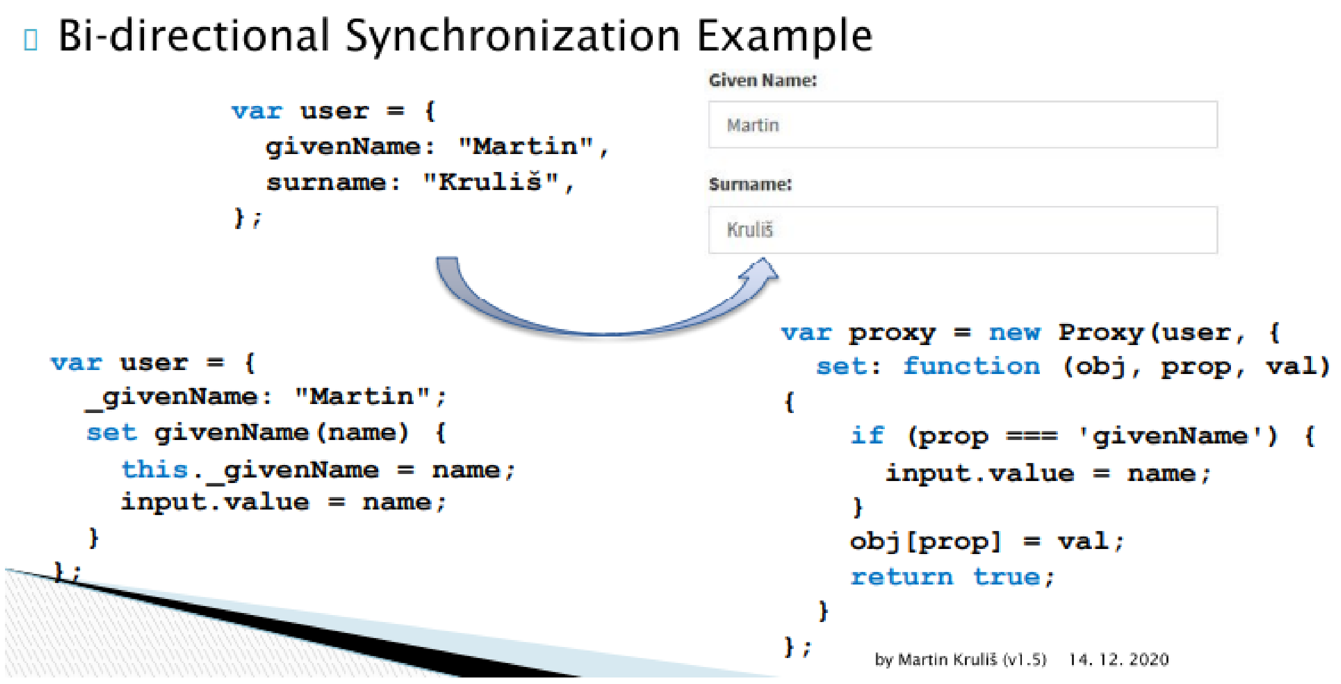
Some binding for user variable may be required

```
document.getElementById('givenName').addEventListener('change', ev => {
    user.givenName = ev.target.value;
});
...
```

```
var user = {
  givenName: "Martin",
  surname: "Kruliš",
};
```

Given Name: Martin

Surname: Kruliš



Bi-directional Synchronization Example

```
var user = {
  givenName: "Martin",
  surname: "Kruliš",
};
```

Given Name: Martin

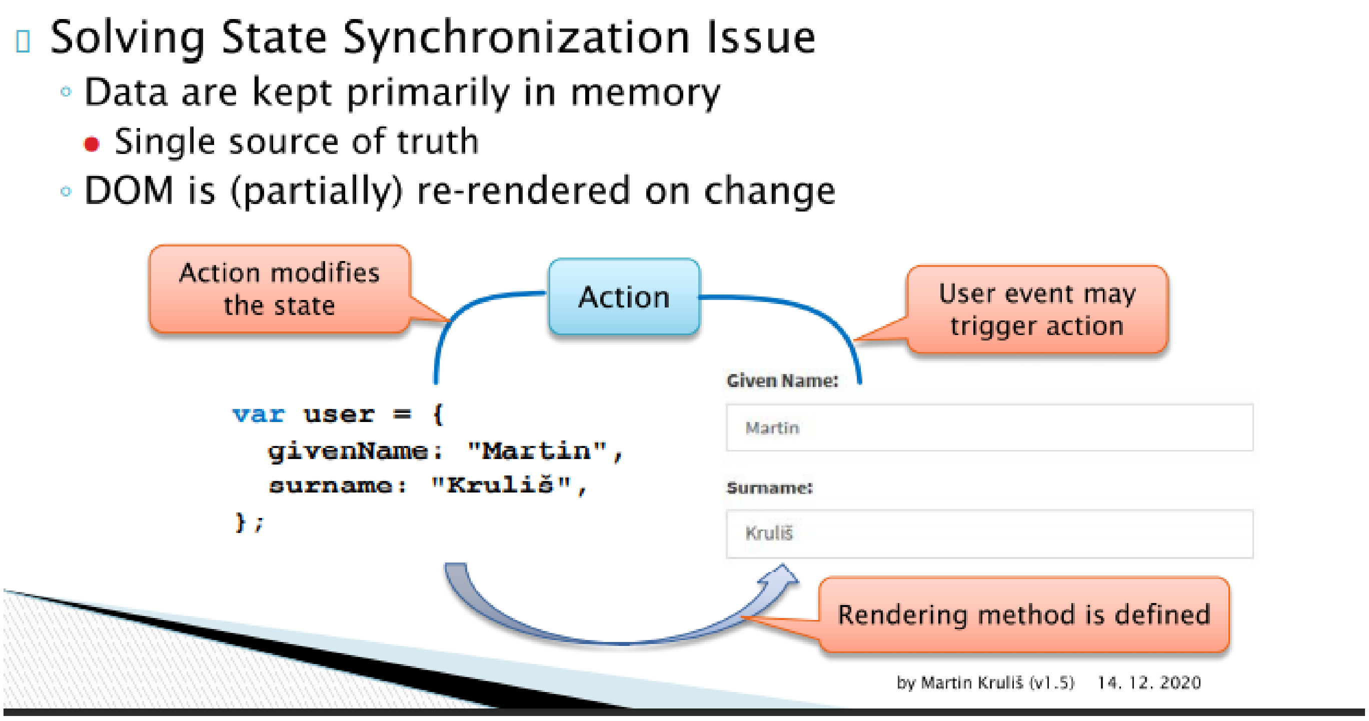
Surname: Kruliš

```
var user = {
  _givenName: "Martin";
  set givenName(name) {
    this._givenName = name;
    input.value = name;
  }
};
```

```
var proxy = new Proxy(user, {
  set: function (obj, prop, val)
{
    if (prop === 'givenName') {
      input.value = name;
    }
    obj[prop] = val;
    return true;
  }
};
```

by Martin Kruliš (v1.5) 14. 12. 2020

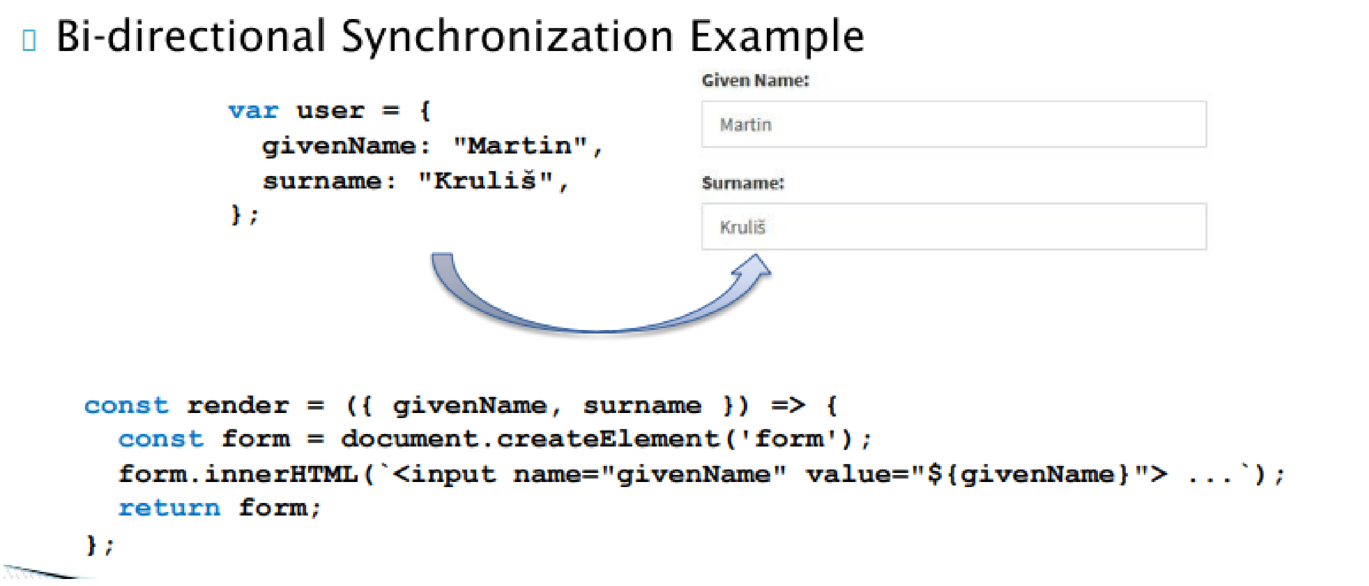
Sync



Solving State Synchronization Issue
- Data are kept primarily in memory
  - Single source of truth
- DOM is (partially) re-rendered on change

```
var user = {
  givenName: "Martin",
  surname: "Kruliš",
};
```

Action modifies the state
Action
User event may trigger action
Given Name:
Martin
Surname:
Kruliš
Rendering method is defined
by Martin Kruliš (v1.5) 14. 12. 2020



Bi-directional Synchronization Example

```
var user = {
  givenName: "Martin",
  surname: "Kruliš",
};
```

```
const render = ({ givenName, surname }) => {
  const form = document.createElement('form');
  form.innerHTML(`<input name="givenName" value="${givenName}"> ...`);
  return form;
};
```

Optimalization

Tips:

- Premature optimization is the root of all evil!
- Efficient event handlers
  - Otherwise the browser may start to lag
- Disjoint DOM nodes assembly
  - When creating DOM subtree, assemble it separately and then insert it to visible DOM all at once
  - Use cloning when possible
  - Prefer hiding/showing of existing nodes using CSS
- Use CSS classes instead of style attributes
  - Especially when operating multiple nodes

AJAX (Asynchronous JavaScript and XML)

A technique that combines three technologies

- JavaScript
- Asynchronous HTTP client API integrated in browser
- XML or other semi-structured data format

Script invokes HTTP transfer

- Providing URL, method, callbacks, ...

The callback is invoked asynchronously

- At the conclusion of the HTTP transfer
- It may process the returned data (e.g., update the contents of the web page)

XMLHttpRequest object

```
var httpReq = new XMLHttpRequest();
httpReq.open("GET", "index.php?ajax=1", true);
httpReq.onreadystatechange = function() {
    if (httpReq.readyState != 4) return;
    if (httpReq.status == 200)
        processResponse(httpReq.responseText);
    else
        handleError(httpReq.status);
}
httpReq.send()
```

JSON (JavaScript Object Notation)

- Lightweight interchange format for structured data
- Based on subset of JavaScript language
- Otherwise language independent
  - Many parsers exist with frontends for many languages
- Intended for replacing XML in simple scenarios

Syntax:

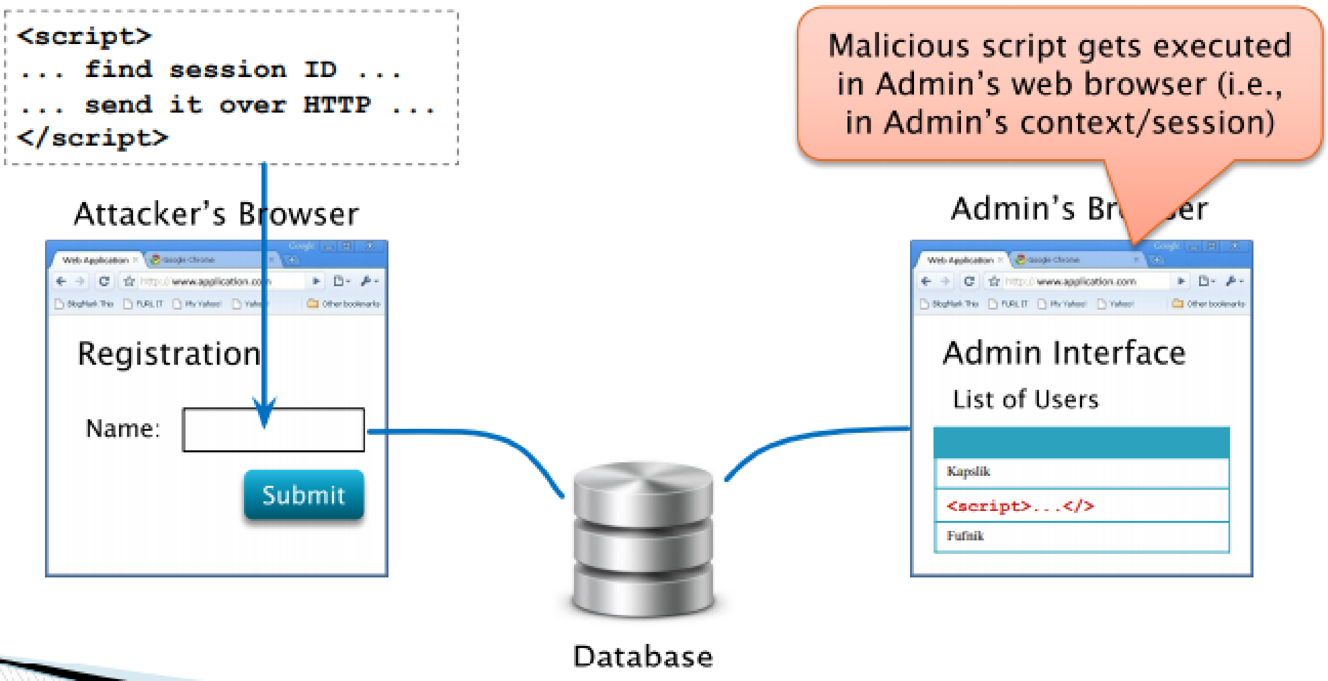
- Two basic structures:
  - collections and
  - lists
- Supports:
  - strings,
  - numbers,
  - bools, and
  - null type
- Unicode safe

```
[
    {
        "StudentId": 42,
        "Name": "John Smith"
    },
    {
        "StudentId": 54,
        "Name": "Jane Johnson",
        "Graduated": true
    }
]
```

Applications

- Mainly for transfer of JavaScript structures
    - AJAJ – Asynchronous JavaScript and JSON
- Parsing
    - ~~`var res = eval(jsonString);`~~
        - Fast but not safe (the string may contain malicious code)
    - `var res = JSON.parse(jsonString);`
        - JSON object was originally implemented in library and later added to ECMAScript 5 standard
- Serialization
    - var jsonString = JSON.stringify(jsObject);

Side note - script injection


```
<script>
... find session ID ...
... send it over HTTP ...
</script>
```

CORS

Cross-site Scripting

- User injects malicious JavaScript into regular data fields (registration form, e-mail body, ...)
- The field is displayed to another user -> the script may steal his/her identity

Prevention

- Browser blocks HTTP requests to other domains
- Browser hides secured cookies from the script

Programmer's Discipline

- All user inputs must be tested or sanitized

Fetch API

New API for AJAX

`fetch(input[, init])`

- input – URL or Request object
- init – object with initialization parameters
  - method – HTTP method to be used
  - headers – request headers
  - body – request body
  - ...
- Returns a promise
  - Promises are async. objects designed to replace callbacks

Promise

Represents eventual completion/failure of async. operation (e.g., AJAX request)

Easy chaining

- `.then(fnc)` – function called on success

```
fetch(url).then(response => ...)
.catch(fnc) // function called on error
.finally(fnc) // called on completion (success or error)
```

Aggregation

- `Promise.all([ promise1, promise2, … ])`
- `Promise.race([ promise1, promise2, … ])`

```
var p = new Promise((resolve, reject) => {
    window.setTimeout(() => {
        resolve('foo');
    }, 300);
});

p.then(value => {
    console.log(value);  // outputs "foo"
});
```

Form Data

Wrapper for Form Data

- Can be used as body for AJAX requests
- Represents a collection of data (as key-value pairs)
    - Analogical to data sent by regular form submit
- Assembled manually or loaded from
    - `new FormData([ formElement ])`
    - `keys()`, `values()`, `entries()`
    - `has()`, `get()`, `getAll()`
    - `set()`, `append()`, `delete()`

Redirects

- Redirecting Asynchronous HTTP Requests
    - Works transparently – i.e., in the same way as all HTTP requests handled by the browser
    - Typically unnecessary after POST requests
        - A script should not be re-executed after reload, thus it can receive the updated HTML immediately
    - Uncertain semantics
        - Is the redirect meant for the AJAX result or should the whole page load a new URL?
    - Efficiency
        - AJAX typically optimizes network utilization – additional redirect may be suboptimal

Example

- Let us have a data table, where each item has a delete button that triggers AJAX POST request

Solutions:

- Trivial solution
    - After successful request, JS triggers reload of the page
        - URL may be in the response body (for location.href)
- Slightly more optimized solution
    - After successful request, JS triggers reload of affected components (table) via separate AJAX GET request
- Optimized solution
    - The POST response sends a HTML fragment or (better yet) component data for re-rendering the table

Page updates

Asynchronous Requests and Page Updates

- E.g., item being deleted by AJAX call
- How/when remove the related DOM contents

Approaches

- Optimistic Updates
  - Item is removed (from DOM) when AJAX is started
  - Problematic if the operation fails
    - Item has to be returned, user may not notice
- Pessimistic Updates
  - Item is removed after AJAX is completed
  - May take long time
    - Progress animation, other operations has to be blocked

HTML5 API

History

New feature – script state (`history.state`)

- `history.pushState()`, `history.replaceState()`
- Captures hidden script-managed state
- Allows backward/forward navigation over the states

Non-visible Data Attributes

- Data for scripts, but associated with DOM elements
- Special `data-*` attributes (e.g., `data-foo-bar`)
- **Appear in `element.dataset` collection**
  - Ad example above – `element.dataset.fooBar`

Data Storage

- Persistence data storage accessible from JS
  - Key-value database
- Similar isolation like cookies
- LocalStorage – persistent, per web application
- SessionStorage – for each window/tab

Web Workers

- Background workers executing JS code
- Utilizing multiple cores
- Communicate by messages with main loop

Compatibility issues

Coding with Multi-browser Support

- Browsers developers implement the web standards when they want and how they want
  - Especially problematic with their older versions

Test the functionality, not the browser type/version

```
if ("XMLHttpRequest" in window) { AJAX code }
else { no AJAX }
```

Use libraries

- Babel – JS transpilling and polyfill
- Webpack – bundling the code (JS and CSS)

jQuery

- Modern JavaScript library for basic operations
  - Easy to learn and use
  - Lightweight footprint
  - Supports almost all currently used browsers
- Key features
  - Simplified DOM traversal and manipulation
  - Event handling
  - CSS based animations and effects
  - Unified AJAX API with support for data (de)serialization
  - Extendable with plugins and UI libraries

jQuery object

Function object in global name jQuery and $ Acts as a function that returns set of nodes and as a container object for library functions

“Select and Do” Philosophy

- Select a set of DOM nodes
- Apply (a sequence of) operation(s) on the whole set of selected nodes
- Most methods support invocation chaining
  - `$(selector).doIt().doAnother().doSometingElse();`

Selectors

Selects set of DOM nodes for further usage

- `$("selector") or $(DOMnode) or $("HTMLfragment")`

jQuery Selectors are inspired by CSS3 selectors

- "`div`" – select elements of given name

- "`#id`" – select element by its ID
- "`.class`" – select elements with specific CSS class
- "`ancestor descendant`" – express DOM relations
- `:disabled`, `:visible`, `:checked`, ...

Subsequent operations work on the whole set

- `$(".secret").hide();`

DOM manipulation functions

- `prepend()`, `append()`, `before()`, `after()` – insert content before/after inside/outside selected elements
- `remove()`, `empty()`, `detach()` – remove (child) nodes
- `replaceAll()`, `replaceWith()`
- `html()`, `text()` – manipulate with content
- `clone()` – create a deep copy of the element
- `attr()`, `prop()`, `removeAttr()`, `removeProp()`
  - Attr ~ HTML attributes, prop ~ properties (checked, ...)

Reading methods take only the first element in set

Single Page Application

- Almost everything is handled by JS (and AJAX)
- No traditional forms or browsing is used

SPA Libraries

- React
  - Uses smart component re-rendering
- Angular
  - Uses bidirectional data bindings (DOM ⇔ data)
- A few others
  - EmberJS, Vue, ...

Security

Main Objective

- Make communication (data storage, ...) secure
- Secure = not readable by 3rd parties, guaranteed to be correct, ...

Alice
Bob
Eve (eavesdropper)

Symmetric Ciphers

- Both sides need to share the same key
- There must be another (secret channel) how they pass on the key
- The key is used both for encryption and decryption

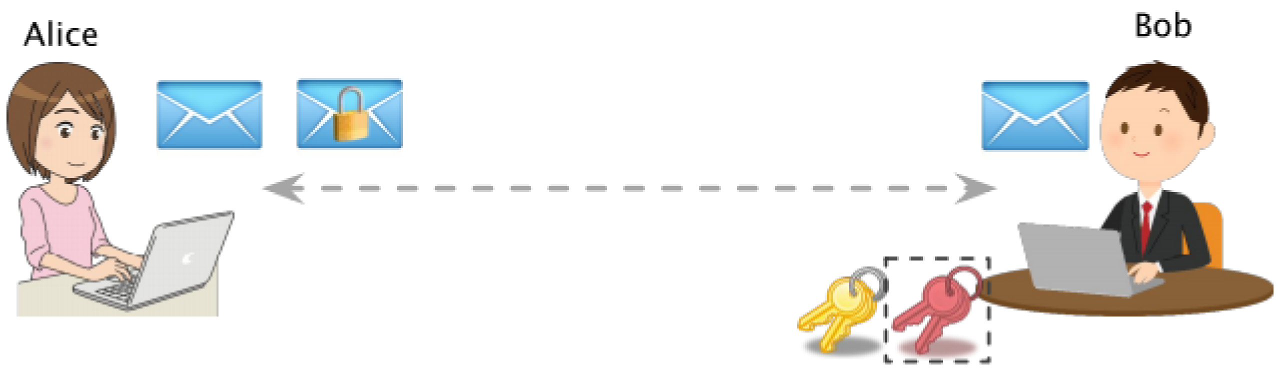
AES

Advanced Encryption Standard (AES) aka Rijndael

- Probably the most popular cipher of the day
- Can use any sequence of bytes as key
    - Keys are expanded into 128, 192, or 256bit blocks
- Works with 4x4 blocks of bytes
- Requires only basic operations (shift, add, xor, ...)
- https://en.wikipedia.org/wiki/Advanced_Encryption_Standard

Asymmetric ciphers (public-key)

- Separate encryption (public) and decryption (private) key
- Does not require secure channel for transmitting the key



Digital signature

- Reversed application of public-key cipher
    - Assumes the decryption/encryption procedures may be swapped
- Sender transforms the message using decryption algorithmb (and private key)
- Anyone transform it back to original using encryption (and public key)
    - And everyone will know that only the person with the corresponding private key could have created the message

RSA

encryption: c = m^e mod n decryption: m = c^d mod n

Heartbleed bug

Ping abuse - return me X letters

Hashing

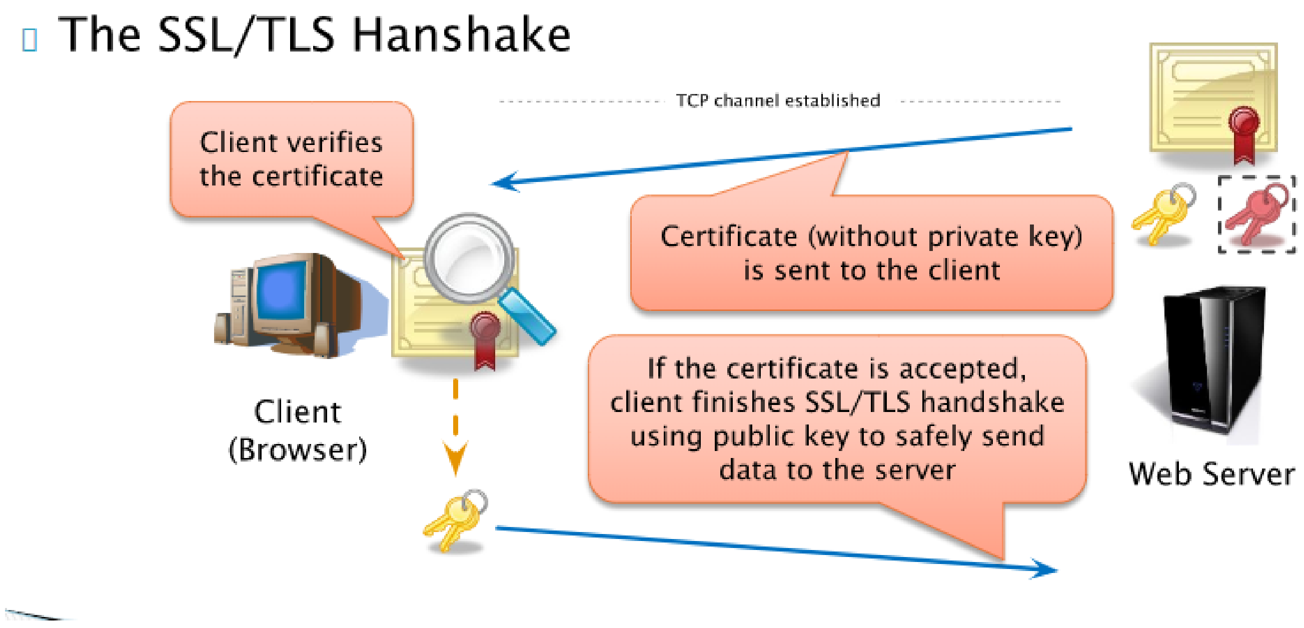
- One-way transformation of data into a fingerprint of fixed size
- Similar (but different) inputs have completely different hashes
- Various applications
    - Integrity verification, passwords, security tokens, ...

Functions

- MD4, MD5, SHA1
    - Obsolete algorithms, still applicable for some cases (e.g., deduplication)
- **SHA-256**, SHA-512, ... (**SHA2**)
    - Quite old, but probably the most widely used hashing algorithm
- SHA3-256, SHA3-512, ...
    - New revision of SHA family, better than SHA2, but not widely used yet
- **bcrypt**, scrypt
    - Specifically designed to be computationally demanding (especially scrypt)
    - More resistant to brute-force attacks (guessing the input)

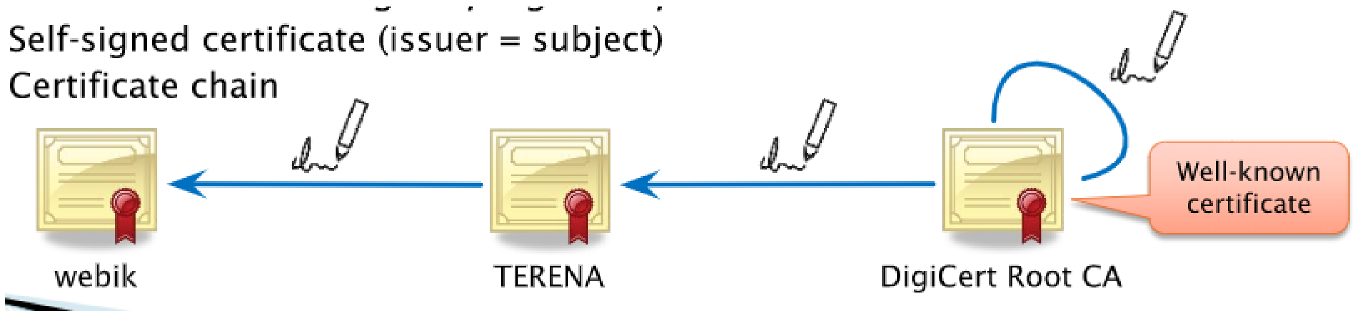
HTTP Secure (HTTPS)

- Insert SSL/TLS layer between TCP and HTTP
- SSL/TLS provides transparent asymmetric encryption
- X.509 Certificates are used
  - Certificate carries the public and private key
  - Certificate has additional info (e.g., a domain name)
  - Every certificate must be signed by another certificate
    - By a certificate of a trustworthy authority
    - By itself (self-signed certificate)
  - Certificate is verified, before its keys are used
    - Usually only the server has a certificate


The SSL/TLS Hanshake
TCP channel established
Client verifies the certificate
Certificate (without private key) is sent to the client
If the certificate is accepted, client finishes SSL/TLS handshake using public key to safely send data to the server
Client (Browser)
Web Server

X.509 Certificates

- Subject name (structured, Common Name = domain)
- Issuer (also structured) – who created (and signed) the certificate
- Validity (not before, not after)
- Optional extensions (e.g., list of alternate domain names)
- Certificate must be digitally signed by the issued
  - Self-signed certificate (issuer = subject)
  - Certificate chain



Security fundamentals

Trusted Base

- Secured server (physically), secured data storage, ...
- May be difficult to ensure (e.g., in Cloud)

Secure Communication

- HTTPS (or other encrypted channels) for all communications
  - Including requests for unimportant things like styles or images
  - Susceptible to common mistakes (especially when dealing with absolute URLs)
- HTTP Strict Transport Security (HSTS)
  - `Strict-Transport-Security` HTTP header instructs the client that given server must be accessed only by encrypted connections (for given period)

Attack Prevention

- Up-to date software (system, libs)
- Due validation/sanitization of inputs/outputs
- Secure session management
  - HTTPS-only cookies, securing session storage or using security tokens, ...
- Second-level authentication and access denial systems
  - Preventing the user to log-in from IP addresses from different countries
  - Two phase authentication (e.g., secondary verification by cell phone)
- Monitoring
  - Attack detection, blacklisting (users, IPs), ...
- Logging

Authentication

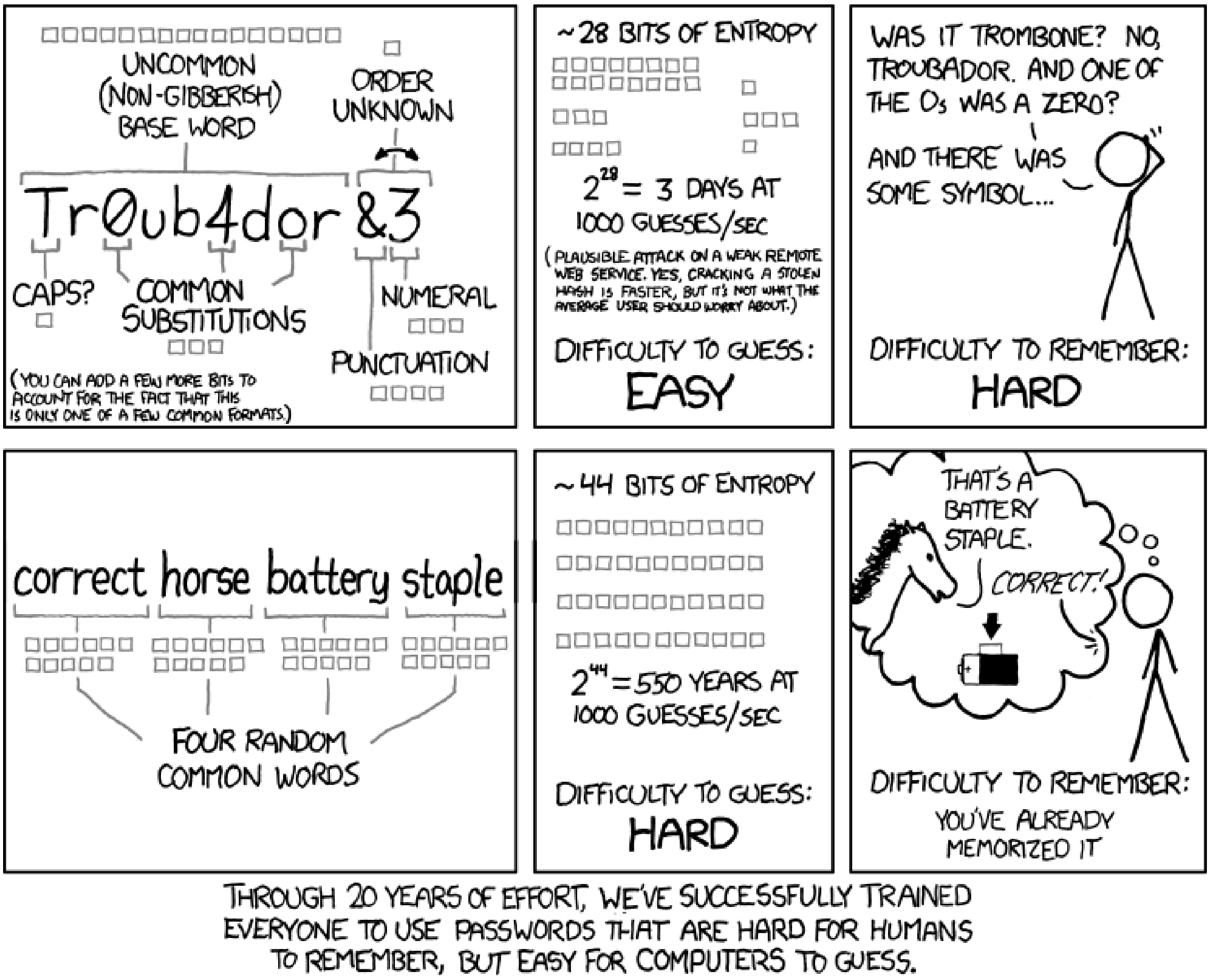
- Verifies identity of a user
  - E.g., by user credentials, by a certificate, ...
- User identity must be held despite statelessness
  - In a (secured) session, in a cookie, ...
- Password security
  - Password should not be stored in plain text nor in decryptable form in the database, but rather hashed
    - `<salt>`, `hashfnc(<salt>,<password>)`
    - The hashfnc could be SHA-256, SHA-512, **bcrypt**, scrypt, ...
  - Salt is necessary to prevent rainbow-table attacks
    - Also to assign different hashes to same passwords used by different users

```
class User {
    private $passwordHash;

    public function setPassword(string $password): void
    {
        $this->passwordHash = password_hash($password,
            PASSWORD_BCRYPT, [ 'cost' => 12 ]);
    }

    public function verifyPassword(string $password): bool
```

```
        {
            return password_verify($password, $this->passwordHash);
        }
    }
```

Password

care with artificially difficult password - easy to brute force


UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor&3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)
~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS: EASY
WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER: HARD
correct horse battery staple
FOUR RANDOM COMMON WORDS
~44 BITS OF ENTROPY
2^44 = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS: HARD
THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER: YOU'VE ALREADY MEMORIZED IT
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

Authentication

(Authentication/Access Tokens)

- Generated once the user is authenticated
  - Or to grant some specific action – e.g., password reset
- Does not have to be private, but only server can create/verify them
- Example of a security token
  - `user_id:salt:hash(user_id:salt:secret)`
  - Where secret is a string known only to the server
- Token may hold additional public data (payload)
  - Expiration timestamp

- Creation timestamp
- Scope – restrictions on actions that the user may do

Authorization

- Verification of the access permissions of the user
- Security Model
  - Defines protected objects, authorities, operations
  - Simple (state-less) models
    - Function (object, authority, operation) -> yes/no
  - More complex models exist
  - Typically implemented in one class (component)
- Roles
  - Authorities are typically not individual users, but roles
  - Each user have one (or multiple) roles

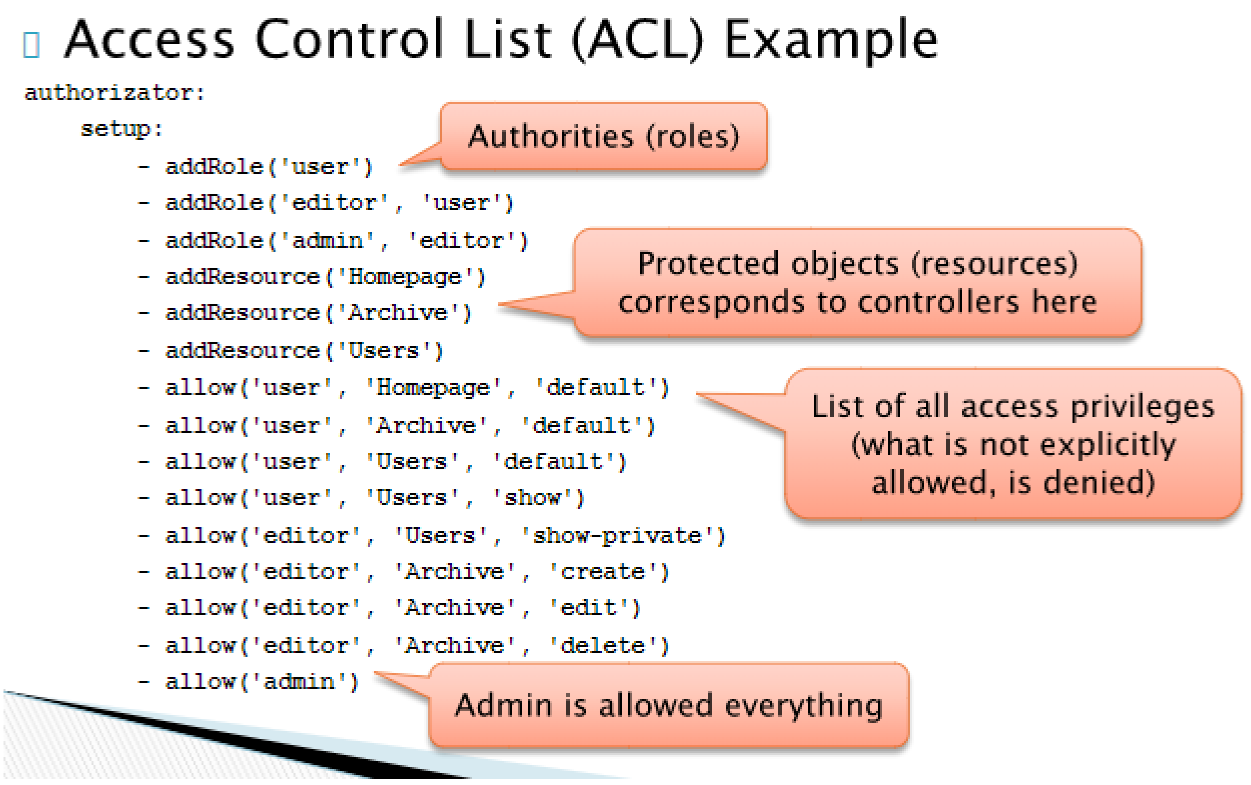
Models

Directory (Capability List)

- Authorities have lists of accessible objects

Access List (ACL)

- Protected objects have lists of users (+permissions)



Access Control List (ACL) Example

```
authorizator:
    setup:
        - addRole('user')
        - addRole('editor', 'user')
        - addRole('admin', 'editor')
        - addResource('Homepage')
        - addResource('Archive')
        - addResource('Users')
        - allow('user', 'Homepage', 'default')
        - allow('user', 'Archive', 'default')
        - allow('user', 'Users', 'default')
        - allow('user', 'Users', 'show')
        - allow('editor', 'Users', 'show-private')
        - allow('editor', 'Archive', 'create')
        - allow('editor', 'Archive', 'edit')
        - allow('editor', 'Archive', 'delete')
        - allow('admin')
```

Authorities (roles)
Protected objects (resources) corresponds to controllers here
List of all access privileges (what is not explicitly allowed, is denied)
Admin is allowed everything

Access Control Matrix

- Rows ~ authorities, cols ~ objects, items ~ access rights

Bell-LaPadula (BLP)

- Each authority has maximal level of access, each object has minimal required level of access

Frontend (UI) vs Backend (REST API/CLI)

- Permissions are primarily tested in backend
- User interface appearance should be in sync with operations the user is authorized to do
- Example – editing an e-shop item
    - Users who do not have the permission to edit should not see the link leading to the page with editing form
    - What if the user gets to the page another way?
    - What if the user switches the role in the middle of editing?
    - How to reveal these permissions to the UI without compromising security?
    - What if the permissions change in the middle of editing?

Logging

Logging Important Events

- Errors
- Security breaches
    - Difficult how to detect them and what to log
- All user actions
    - May be impossible for large systems, so at least "important" actions
    - Logging at request level
    - Logging at database level (DB triggers)

Delayed Operations

- Soft-deletes
- Queued operations