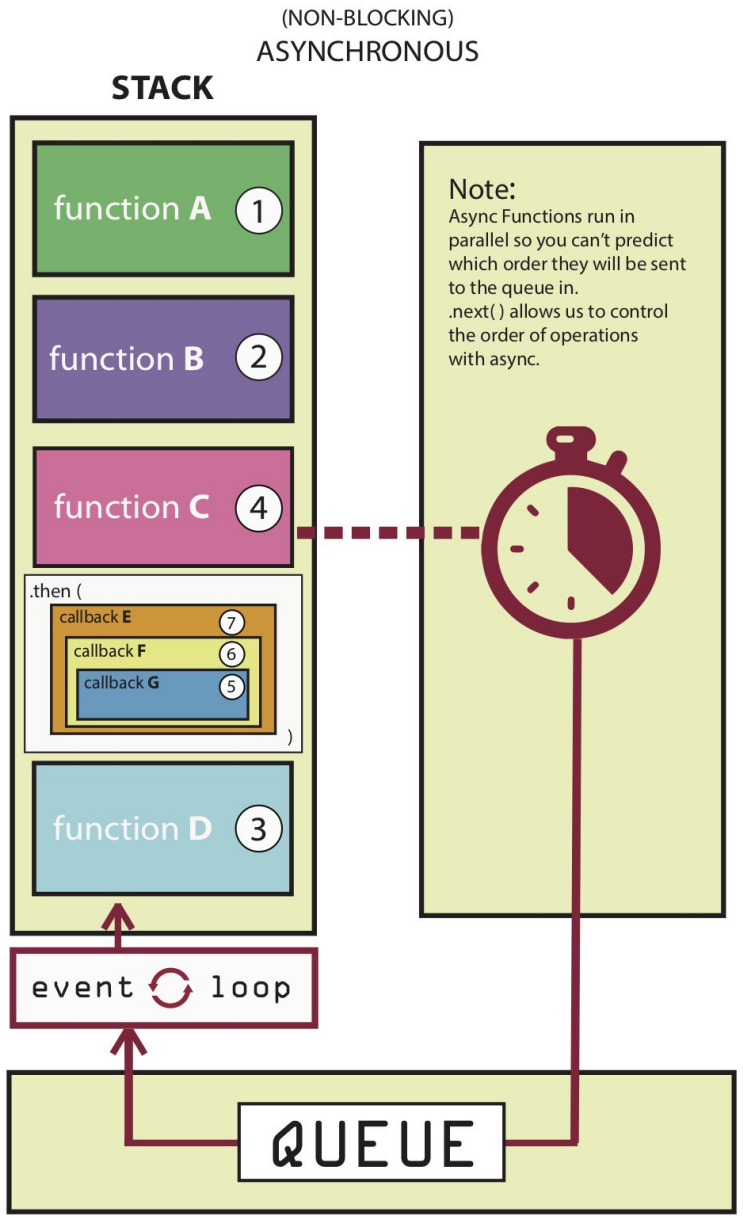
<WA1/>

2020

Asynchronous Programming in JS

"The" language of the Web

Enrico Masala
Fulvio Corno
Luigi De Russis



JavaScript: The Definitive Guide, 7th Edition
Chapter 11. Asynchronous JavaScript

Mozilla Developer Network

- Learn web development JavaScript » Dynamic client-side scripting » Asynchronous JavaScript
- Web technology for developers » JavaScript » Concurrency model and the event loop
- Web technology for developers » JavaScript » JavaScript Guide » Using Promises

JavaScript – The language of the Web

ASYNCHRONOUS PROGRAMMING

Asyncronicity

- JavaScript is single-threaded and inherently synchronous
  - i.e., code cannot create threads and run in parallel in the JS engine
- Callbacks are the most fundamental way for writing asynchronous JS code
- How can they work asynchronously?
  - e.g., how can setTimeout() or other async callbacks work?
- Thanks to the Execution Environment
  - e.g., browsers and Node.js
- and the Event Loop

```
const deleteAfterTimeout = (task) =>
{
  // do something
}
// runs after 2 seconds
setTimeout(deleteAfterTimeout, 2000,
task)
```

Non-Blocking Code!

- Asynchronous techniques are very useful, particularly for web development
- For instance: when a web app runs executes an intensive chunk of code without returning control to the browser, the browser can appear to be frozen
  - this is called blocking, and it should be the exception!
    - the browser is blocked from continuing to handle user input and perform other tasks until the web app returns control of the processor
- This may happen outside browsers, as well
  - e.g., reading a long file from the disk/network, accessing a database and returning data, accessing a video stream from a web cam, etc.
- Most of the JS execution environments are, therefore, deeply asynchronous
  - with non-blocking primitives
  - JavaScript programs are event-driven, typically

Back to Callbacks

- The most fundamental way for writing asynchronous JS code
- Great for "simple" things!

```
const readline = require('readline');

const rl = readline.createInterface({
    input: process.stdin,
    output: process.stdout
});

rl.question('Task description: ', (answer) => {
    let description = answer;

    rl.close();
});
```

Handling Errors in Callbacks

- No “official” ways, only best practices!
- Typically, the first parameter of the callback function is for storing any error, while the second one is for the result of the operation
  - this is the strategy adopted by Node.js, for instance

```
fs.readFile('/file.json', (err, data) => {
  if (err !== null) {
    console.log(err);
    return;
  }
  //no errors, process data
  console.log(data);
});
```

Beware: Callback Hell!

- If you want to perform multiple asynchronous actions in a row using callbacks, you must keep passing new functions to handle the continuation of the computation after the previous action
  - every callback adds a level of nesting
  - when you have lots of callbacks, the code starts to be complicated very quickly

```
const readline = require('readline');
const rl = readline.createInterface(...);

rl.question('Task description: ', (answer) => {
  let description = answer;

  rl.question('Is the task important? (y/n)', (answer) => {
    let important = answer;

    rl.question('Is the task private? (y/n)', (answer) => {
      let private = answer;

      rl.question('Task deadline: ', (answer) => {
        let date = answer;
        ...
      }
    }
  }

  rl.close();

});
```

Callback Hell

```
window.addEventListener('load', () => {
  document.getElementById('button').addEventListener('click', () => {
    setTimeout(() => {
      items.forEach(item => {
        //your code here
      })
    }, 2000);
  })
})
```

Promises

- A core language feature to simplify asynchronous programming
  - a possible solution to callback hell, too!
  - a fundamental building block for "newer" functions (async, ES2017)
- It is an **object** representing the eventual **completion** (or **failure**) of an asynchronous operation
  - i.e., an asynchronous function returns *a promise to supply the value* at some point in the future, instead of returning immediately a final value
- Promises standardize a way to handle errors and provide a way for errors to propagate correctly through a chain of promises

Promises

- Promises can be created or consumed
  - many Web APIs expose Promises to be consumed!
- When consumed:
  - a Promise starts in a **pending** state
    - the caller function continues the execution, while it waits for the Promise to do its own processing, and give the caller function some "responses"
  - then, the caller function waits for it to either return the promise in a fulfilled state or in a rejected state

```
let duration = 10;

const waitPromise = new Promise((resolve, reject)
=> {
  if (duration >= 0) {
  // the promise can be fulfilled!
    resolve("It works!");
  } else {
    // time travel? we reject the promise
    reject(new Error("It doesn't work."));
  }
});

waitPromise.then((result) => {
  console.log("Success: ", result);
}).catch((error) => {
  console.log("Error: ", error);
});
```

Creating a Promise

- A Promise object is created using the new keyword and its constructor
- The constructor takes an *executor function*, as its parameter
- This function takes two functions as parameters:
  - `resolve`, called when the asynchronous task completes successfully and returns the results of the task as a value
  - `reject`, called when the task fails and returns the reason for failure (an error object, typically)

```
const myPromise = new Promise((resolve,
reject) => {

// do something asynchronous which
eventually call either:

   resolve(someValue); // fulfilled

// or

   reject("failure reason"); // rejected

});
```

Creating a Promise

- You can also provide a function with “promise functionality”
- Simply have it return a promise!

```
function wait(duration) {
  // Create and return a new promise
  return new Promise((resolve, reject) => {

  // If the argument is invalid, reject the
promise
  if (duration < 0) {
    reject(new Error('Time travel not yet
implemented'));
  }

  // otherwise, wait asynchronously and then resolve the
Promise
  // setTimeout will invoke resolve() with no arguments:
  // the Promise will fulfill with the undefined value
  setTimeout(resolve, duration);
  });
}
```

Consuming a Promise

- When a Promise is fulfilled, the `then()` callback is used
- If a Promise is rejected, instead, the `catch()` callback will handle the error
- `then()` and `catch()` are instance methods defined by the Promise object
  - each function registered with then() is invoked only once
- You can omit catch(), if you are interested in the result, only

```
waitPromise.then((result) => {
  console.log("Success: ", result);
}).catch((error) => {
  console.log("Error: ", error);
});

// if a function returns a Promise...
wait(1000).then(() => {
  console.log("Success!");
}).catch((error) => {
  console.log("Error: ", error);
});
```

Consuming a promise

- `p.then(onFulfilled[, onRejected]);`
  - Callbacks are executed asynchronously (inserted in the event loop) when the promise is either fulfilled (success) or rejected (optional)
- `p.catch(onRejected);`
  - Callback is executed asynchronously (inserted in the event loop) when the promise is rejected
- `p.finally(onFinally);`
  - Callback is executed in any case, when the promise is either fulfilled or rejected.
  - Useful to avoid code duplication in then and catch handlers
- All these methods return Promises, too!

Chaining Promises

- One of the most important benefits of Promises
- They provide a natural way to express a sequence of asynchronous operations as a linear chain of `then()` invocations
  - without having to nest each operation within the callback of the previous one
    - the "callback hell" seen before
- Important: Always return results, otherwise callbacks won't get the result of a previous promise

```
getRepoInfo()
  .then(repo => getIssue(repo))
  .then(issue => getOwner(issue.ownerId))
  .then(owner => sendEmail(owner.email,
'Some text'))
  .catch(e => {
    // just log the error
    console.error(e)
  })
  .finally(_ => logAction());
});
```

Example Chaining

- Useful, for instance, with I/O API such as `fetch()`, which returns a Promise

```
const status = (response) => {
  if (response.status >= 200 && response.status < 300) {
    return Promise.resolve(response)   // static method to return a fulfilled Promise
  }
  return Promise.reject(new Error(response.statusText))
}
const json = (response) => response.json()

fetch('/todos.json')
  .then(status)
  .then(json)
  .then((data) => { console.log('Request succeeded with JSON response', data) })
  .catch((error) => { console.log('Request failed', error) })
```

Promises… in Parallel

```
Promise.all(promises)
  .then(results => console.log(results);
  })
  .catch(e => console.error(e));
```

- What if we want to execute several asynchronous operations in parallel?
- Promise.all()
  - takes an array of Promise objects as its input and returns a Promise
  - the returned Promise will be rejected if at least one of the input Promises is rejected
  - otherwise, it will be fulfilled with an array of the fulfillment values for each of the input promises
  - the input array can contain non-Promise values, too: if an element of the array is not a Promise, it is simply copied unchanged into the output array
- Promise.race()
  - returns a Promise that is fulfilled or rejected when the first of the Promises in the input array is fulfilled or rejected
  - if there are any non-Promise values in the input array, it simply returns the first of those

Simplyfing writing with async / await

- ECMAScript 2017 (**ES8**) introduces two new keywords **`async await`**
  - write promise-based asynchronous code that looks like synchronous code
- Prepend `async` keyword to any function means that it will return a promise
- Prepend `await` when calling an async function (or a function returning a Promise) makes the calling code stop until the promise is resolved or rejected

```
const sampleFunction = async () => {
  return 'test'
}
sampleFunction().then(console.log) // This will log 'test'
```

async functions

- The async function declaration defines an asynchronous function
  - a function that is an AsyncFunction object
- Asynchronous functions operate in a separate order than the rest of the code via the **event loop**, returning an **implicit Promise** as their result
  - but the syntax and structure of code using async functions looks like standard synchronous functions.

```
async function name([param[, param[, ...param]]]) {
statements }
```

https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Statements/async_function

await

- The await operator can be used to wait for a Promise. It can *only be used inside an async function*
- await **blocks** the code execution within the async function **until the Promise is resolved**
- When resumed, the value of the await expression is that of the fulfilled Promise
- If the Promise is rejected, the await expression throws the rejected value
  - If the value of the expression following the await operator is not a Promise, it's converted to a resolved Promise

```
returnValue = await expression;
```

https://developer.mozilla.org/en-US/docs/Web/JavaScript/Reference/Operators/await

Example: async / await

```
function resolveAfter2Seconds() {
  return new Promise(resolve => {
    setTimeout(() => {
      resolve('resolved');
    }, 2000);
  });
}
async function asyncCall() {
  console.log('calling');
  const result = await resolveAfter2Seconds();
  console.log(result);
}

asyncCall();
```

Return a promise

`async` is needed to use `await`

Looks like sequential code

```
> "calling"
//... 2 seconds
> "resolved"
```

Example: async / await

```
function resolveAfter2Seconds() {
  return new Promise(resolve => {
    setTimeout(() => {
      resolve('resolved');
    }, 2000);
  });
}
async function asyncCall() {
  console.log('calling');
  const result = await resolveAfter2Seconds();
  return 'end';
}

asyncCall().then(console.log);
```

Implicitly returns a `Promise`

Can use Promise methods

```
> "calling"
//... 2 seconds
> "end"
```

Examples… Before and After

```
const makeRequest = () => {
  return getAPIData()
    .then(data => {
      console.log(data);
      return "done";
    }
  );
}

let res = makeRequest();
```

```
const makeRequest = async () => {
  console.log(await getAPIData());
  return "done";
};

let res = makeRequest();
```

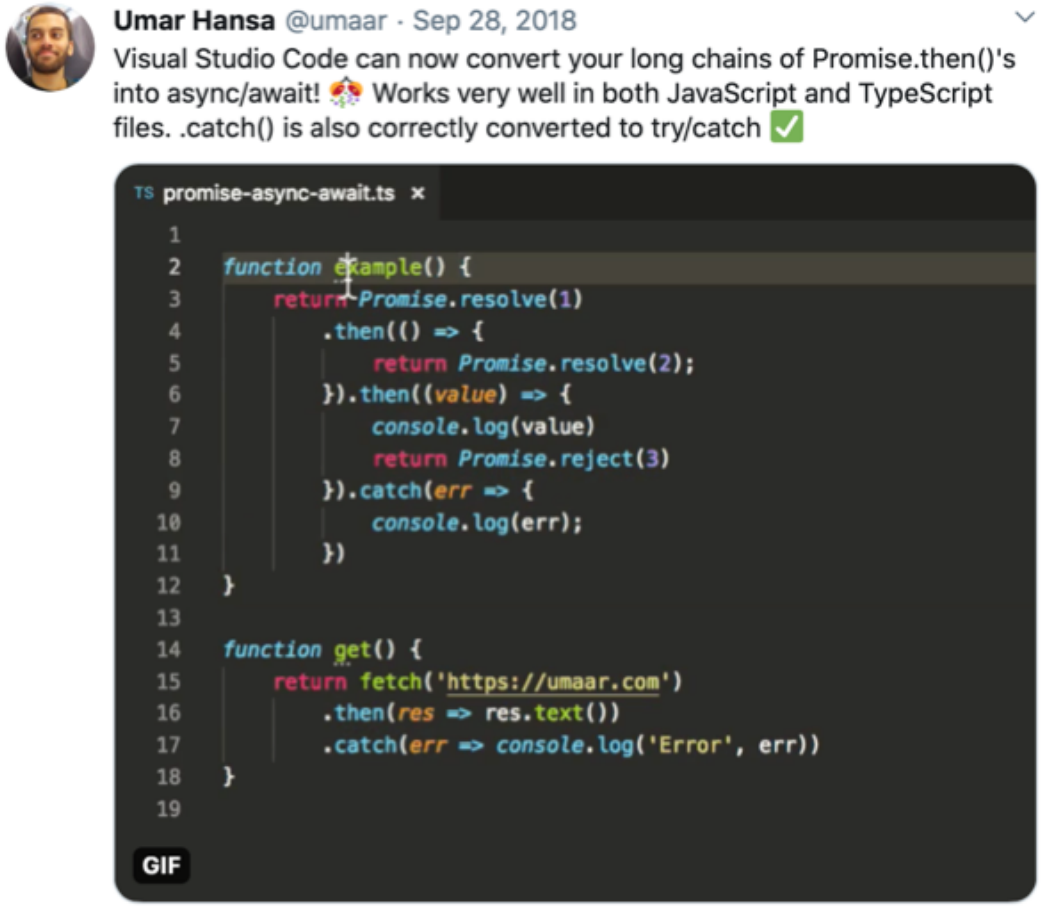
Examples… Before and After

```
function getData() {
  return getIssue()
    .then(issue =>
getOwner(issue.ownerId))
    .then(owner =>
sendEmail(owner.email, 'Some text'));
}

// assuming that all the 3 functions
above return a Promise
```

```
async function getData = {
  const issue = await getIssue();
  const owner = await
getOwner(issue.ownerId);
  await sendEmail(owner.email, 'Some
text');
}
```

Converting Promise-based Function to async/await with Visual Studio Code



https://twitter.com/i/status/1045655069478334464

Chaining with async/await

- Simpler to read, easier to debug
  - debugger would not stop on asynchronous code

```
const getFirstUserData = async () => {
  const response = await fetch('/users.json'); // get users list
  const users = await response.json(); // parse JSON
  const user = users[0]; // pick first user
  const userResponse = await fetch(`/users/${user.name}`); // get user data
  const userData = await user.json(); // parse JSON
  return userData;
}
getFirstUserData()
```

Promises or async/await? Both!

- If the output of `function2` is dependent on the output of `function1`, use `await`.
- If two functions can be run in parallel, create two different async functions and then run them in parallel `Promise.all(promisesArray)`
- Instead of creating huge async functions with many await asyncFunction() in it, it is better to create **smaller** async functions (not too much blocking code)
- If your code contains blocking code, it is better to make it an async function. The callers can decide on the level of asynchronicity they want.

https://medium.com/better-programming/should-i-use-promises-or-async-await-126ab5c98789

License

- These slides are distributed under a Creative Commons license “**Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0)**”
- **You are free to:**
  - **Share** — copy and redistribute the material in any medium or format
  - **Adapt** — remix, transform, and build upon the material
  - The licensor cannot revoke these freedoms as long as you follow the license terms.
- **Under the following terms:**
  - **Attribution** — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.
  - **NonCommercial** — You may not use the material for commercial purposes.
  - **ShareAlike** — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original.
  - **No additional restrictions** — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.
- https://creativecommons.org/licenses/by-nc-sa/4.0/