Asynchronous Programming in JS

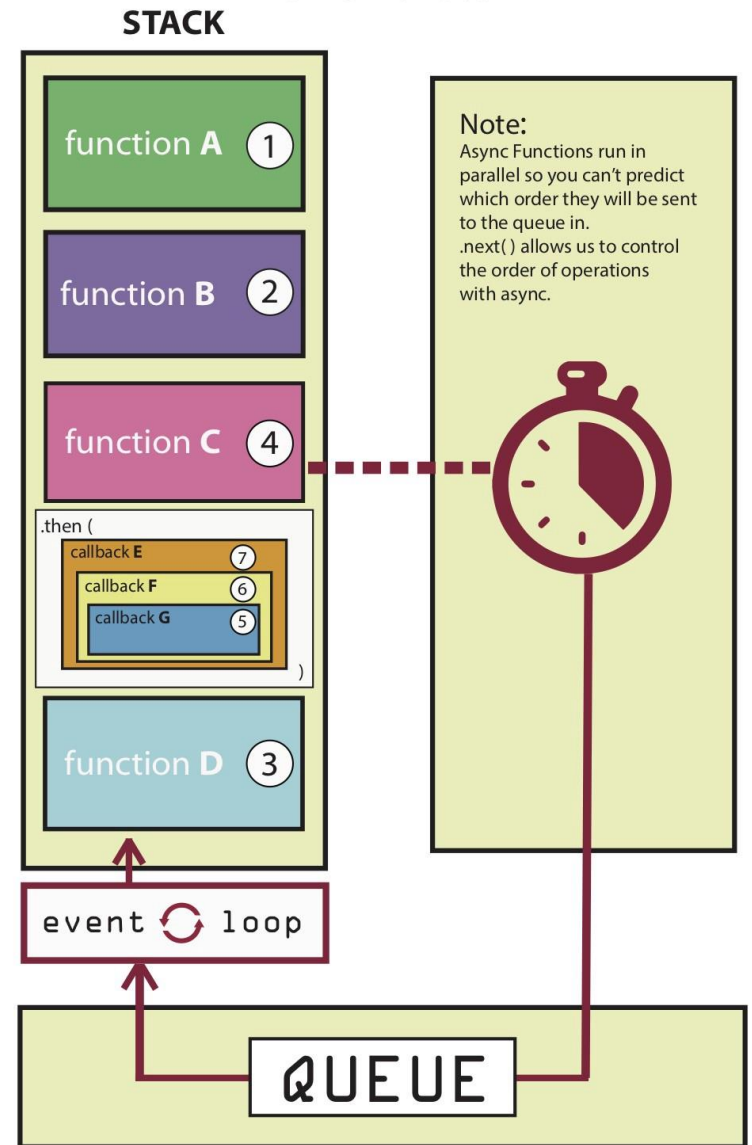**"The" language of the Web**

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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)
```

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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

```javascript
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

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

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