Promise

Building Modern Web Applications - VSP2022

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What is a Promise

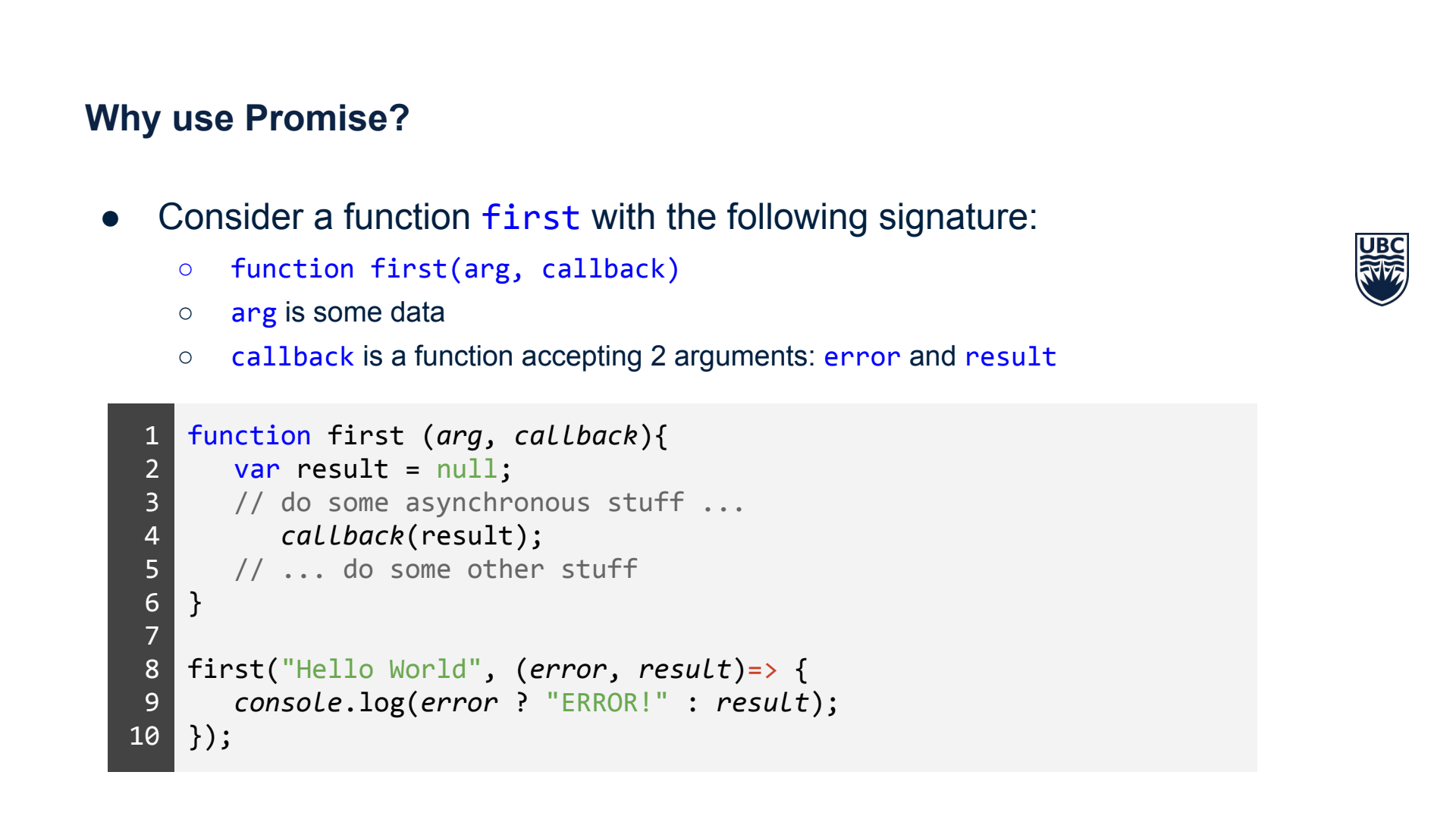
1. **What is a Promise**
2. How to use Promises
3. Asynchronous Programming with Promises

What is a Promise

- Promise is a new built-in object **introduced in ES6**
- Provides a **cleaner interface** for handling **asynchronous operations**
- When multiple asynchronous operations need to be made, the **callback** pattern **becomes hard to follow**
  - Scope of variables in multiple nested closures
  - Error handling for each of the callback steps

Why use Promise?

- Consider a function `first` with the following signature:
  - `function first(arg, callback)`
  - `arg` is some data
  - `callback` is a function accepting 2 arguments: `error` and `result`



```
1  function first (arg, callback){
2     var result = null;
3     // do some asynchronous stuff ...
4        callback(result);
5     // ... do some other stuff
6  }
7
8  first("Hello World", (error, result)=> {
9     console.log(error ? "ERROR!" : result);
10 });
```

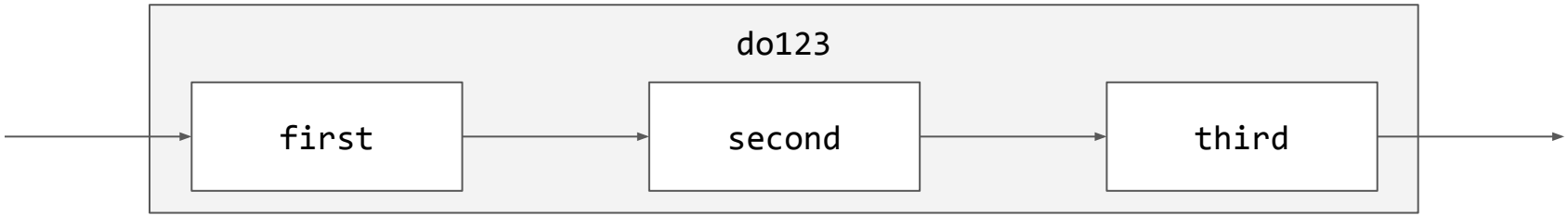
Why use Promise?

- Consider 2 more functions with similar function signatures:
  - `function second(arg, callback)`
  - `function third(arg, callback)`
- How to create a new function that calls the 3 functions in sequence?

```
1  function first (arg, callback){ /* some code */ };
2  function second (arg, callback){ /* some code */ };
3  function third (arg, callback){ /* some code */ };
4
5  function do123(arg, callback){
6     /*
7      Call first, second, then third.
8      After everything is done, call the callback
9      */
10 }
```

Why use Promise?

- Consider 2 more functions with similar function signatures:
  - `function second(arg, callback)`
  - `function third(arg, callback)`
- How to create a new function that calls the 3 functions in sequence?



Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
function do123(arg, callback){



}


```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3
4
5
6
7
8     });
9  }
10
11
12
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        second(result1, (err2, result2)=> {
4
5
6
7        });
8     });
9  }
10
11
12
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        second(result1, (err2, result2)=> {
4           third(result2, (err3, result3)=> {
5
6           });
7        });
8     });
9  }
10
11
12
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        second(result1, (err2, result2)=> {
4           third(result2, (err3, result3)=> {
5              callback(null, result3);
6           });
7        });
8     });
9  }
10
11
12
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        if (err1) callback(err1);
4        else second(result1, (err2, result2)=> {
5           third(result2, (err3, result3)=> {
6              callback(null, result3);
7           });
8        });
9     });
10 }
11
12
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        if (err1) callback(err1);
4        else second(result1, (err2, result2)=> {
5           if (err2) callback(err2);
6           else third(result2, (err3, result3)=> {
7              callback(null, result3);
8           });
9        });
10    });
11 }
12
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        if (err1) callback(err1);
4        else second(result1, (err2, result2)=> {
5           if (err2) callback(err2);
6           else third(result2, (err3, result3)=> {
7              if (err3) callback(err3);
8              else callback(null, result3);
9           });
10       });
11    });
12 }
```

Why use Promise?

- How to create a new function that calls the 3 functions in sequence?

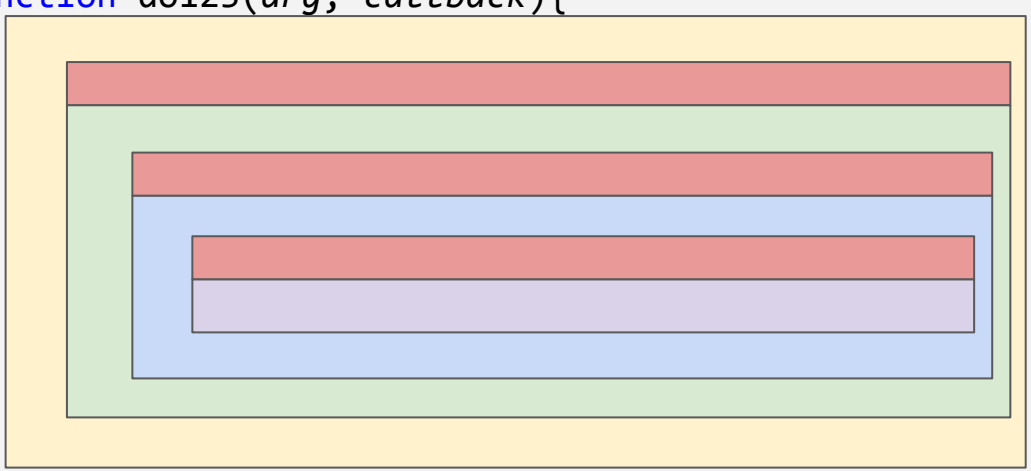
```
1  function do123(arg, callback){
2     first(arg, (err1, result1)=> {
3        if (err1) callback(err1);
4        else second(result1, (err2, result2)=> {
5           if (err2) callback(err2);
6           else third(result2, (err3, result3)=> {
7              if (err3) callback(err3);
8              else callback(null, result3);
9           });
10       });
11    });
12 }
```

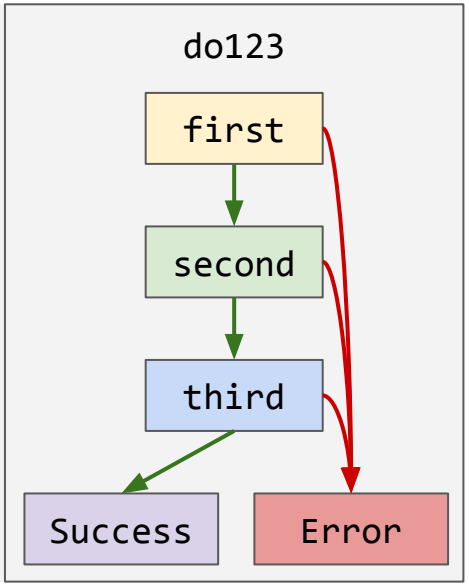
Callback Hell

Why use Promise?

- Problem with callbacks: the **code structure does not follow** the **logical structure**

```
1  function do123(arg, callback){
2
3
4
5
6
7
8
9
10
11
12 }
```

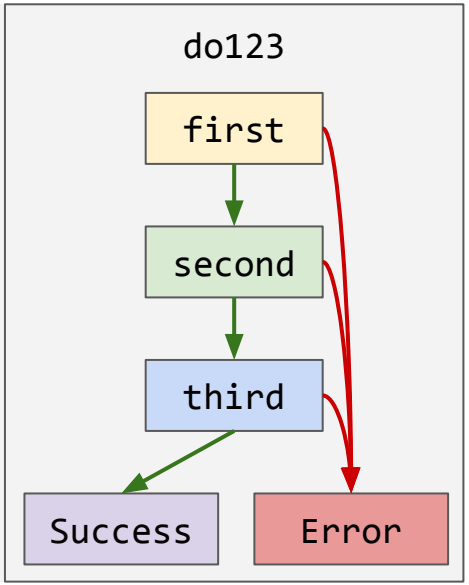




Why use Promise?

- It would be nice if the **code structure followed** the **logical structure**

```
1  function do123(arg, callback){
2
3
4
5
6
7
8
9
10
11
12 }
```



Why use Promise?

- Consider the same `first` function using a `Promise`-based interface
  - `function first(arg)` - notice the lack of a `callback` argument
  - `arg` is some data
  - returns a `Promise` object

```
1  function first (arg, callback){
2     var result = null;
3     // do some asynchronous stuff ...
4        callback(result);
5     // ... do some other stuff
6  }
7
8  first("Hello World", (error, result)=> {
9     console.log(error ? "ERROR!" : result);
10 });
```

Why use Promise?

- Consider the same `first` function using a `Promise`-based interface
  - `function first(arg)` - notice the lack of a `callback` argument
  - `arg` is some data
  - returns a `Promise` object

```
1  function first (arg){
2     return new Promise((resolve, reject)=> {
3        var result = null;
4        // do some asynchronous stuff ...
5           resolve(result);
6        // ... do some other stuff
7     });
8  }
9  first("Hello World")
10  .then(console.log, (error)=> console.log("ERROR!"));
```

Why use Promise?

Using ES5 Callbacks

```
1  function do123(arg, callback){
2   first(arg,
3   (err1, result1)=> {
4    if (err1) callback(err1);
5    else second(result1,
6    (err2, result2)=> {
7     if (err2) callback(err2);
8     else third(result2,
9     (err3, result3)=> {
10     if (err3) callback(err3);
11     else
12      callback(null, result3);
13    });  });  });
14 }
```

Using ES6 Promises

```
1  function do123(arg){
2     return first(arg)
3        .then(second)
4        .then(third)
5  }
6
7
8
9
10
11
12
13
14
```

How to use Promises

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Promise

- `Promise` is an object with the following methods
  - `then (onResolve, onReject)`: used to register resolve and reject callbacks
  - `catch (onReject)`: used to register reject callback
  - `finally (onComplete)`: used to register settlement callback
- `Promise` will be in one of the three states: pending, resolved, rejected
- `Promise` also has static methods
  - `resolve (value)`: returns a `Promise` that resolves immediately to `value`
  - `reject (error)`: returns a `Promise` that rejects immediately to `error`
  - `all (promises)`: returns a `Promise` that resolves when all promises resolve
  - `race (promises)`: returns a `Promise` that resolves if any of the promises resolve

Promise

- Creating a `Promise` object
  - `new Promise(func)`: The `Promise` constructor expects a single argument *`func`*, which is a function with 2 arguments: `resolve`, `reject`
  - `resolve` and `reject` are callback functions for emitting the result of the operation
    - `resolve(result)` to emit the result of a successful operation
    - `reject(error)` to emit the error from a failed operation

```
1  var action = new Promise((resolve, reject)=> {
2     var result = null;
3     // do some asynchronous stuff ...
4     if (noError) resolve(result);
5     else reject(new Error("Something Wrong"));
6     // ... do some other stuff
7  });
```

Promise

- Creating a `Promise` object
  - `new Promise(func)`: The `Promise` constructor expects a single argument *`func`*, which is a function with 2 arguments: `resolve`, `reject`
  - `resolve` and `reject` are callback functions for emitting the result of the operation
    - `resolve(result)` to emit the result of a successful operation
    - `reject(error)` to emit the error from a failed operation

```
1  var action = new Promise((resolve, reject)=> {
2     setTimeout(()=> {
3        if (Math.random() > 0.5) resolve("Success!");
4        else reject(new Error("LowValueError"));
5     }, 1000);
6  });
7
```

Promise

- Using the result of a `Promise` fulfillment through the `then` method
  - `then(onResolve, onReject)`: used to register callbacks for handling the result of the `Promise`. It returns another `Promise`, making this function **chainable**
  - `onResolve` is called **if the previous `Promise` resolves**; it receives the resolved value as the only argument
  - `onReject` is called **if the previous `Promise` rejects** or **throws an error**; it receives the rejected value or the error object as the only argument

```
1  action.then(
2     (result)=> console.log(result), // result: "Success!"
3     (error)=> console.log(error)    // error: Error("LowValueError")
4  );
5
6
```

Promise

- Using the result of a `Promise` fulfillment through the `then` method
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```
1  action.then(
2     (result)=> console.log(result), // result: "Success!"
3     (error)=> console.log(error)    // error: Error("LowValueError")
4  )
5  .then(()=> console.log("A"));
6
```

Promise

- Using the result of a `Promise` fulfillment through the `then` method
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```
1  action.then(
2     (result)=> console.log(result), // result: "Success!"
3     (error)=> console.log(error)    // error: Error("LowValueError")
4  )
5  .then(()=> console.log("A"))
6  .then(()=> console.log("B"));
```

Class Activity: Promise Chaining

 lectures/lecture-9/activity1.js

- Create a `resolveAfter` function that resolves after a specified amount of *`time`*, returning a `Promise` object
  - The function should print the given `time` before resolving
- Using the `resolveAfter` function and the `then` method to chain the promises, make the program print 500, 1000, 1500 one after another

```
1  function resolveAfter (time){
2     // to implement
3  }
4
5  resolveAfter(500)
6  .then(/* to implement */)
```

Promise

- The `catch` method is used to handle the result of a rejected `Promise`
  - `catch(onReject)`: used to register a callback for handling the result of the failed `Promise`. It returns another `Promise`, making this function **chainable**
  - `onReject` is called **if the previous `Promise` rejects** or **throws an error**; it receives the rejected value or the error object as the only argument

```
action.then(
   (result)=> console.log(result), // result: "Success!"
   (error)=> console.log(error)    // error: Error("LowValueError")
)
.catch((err)=> console.log(err));

```

Promise

- The `finally` method is used to register a callback to be called when a `Promise` is settled, regardless of the result
  - `finally(onComplete)`: It returns another `Promise`, making this function **chainable**
  - `onComplete` is called **if the previous `Promise` is settled**


```
1  action.then(
2     (result)=> console.log(result), // result: "Success!"
3     (error)=> console.log(error)    // error: Error("LowValueError")
4  )
5  .catch((err)=> console.log(err))
6  .finally(()=> console.log("The End!"));
```

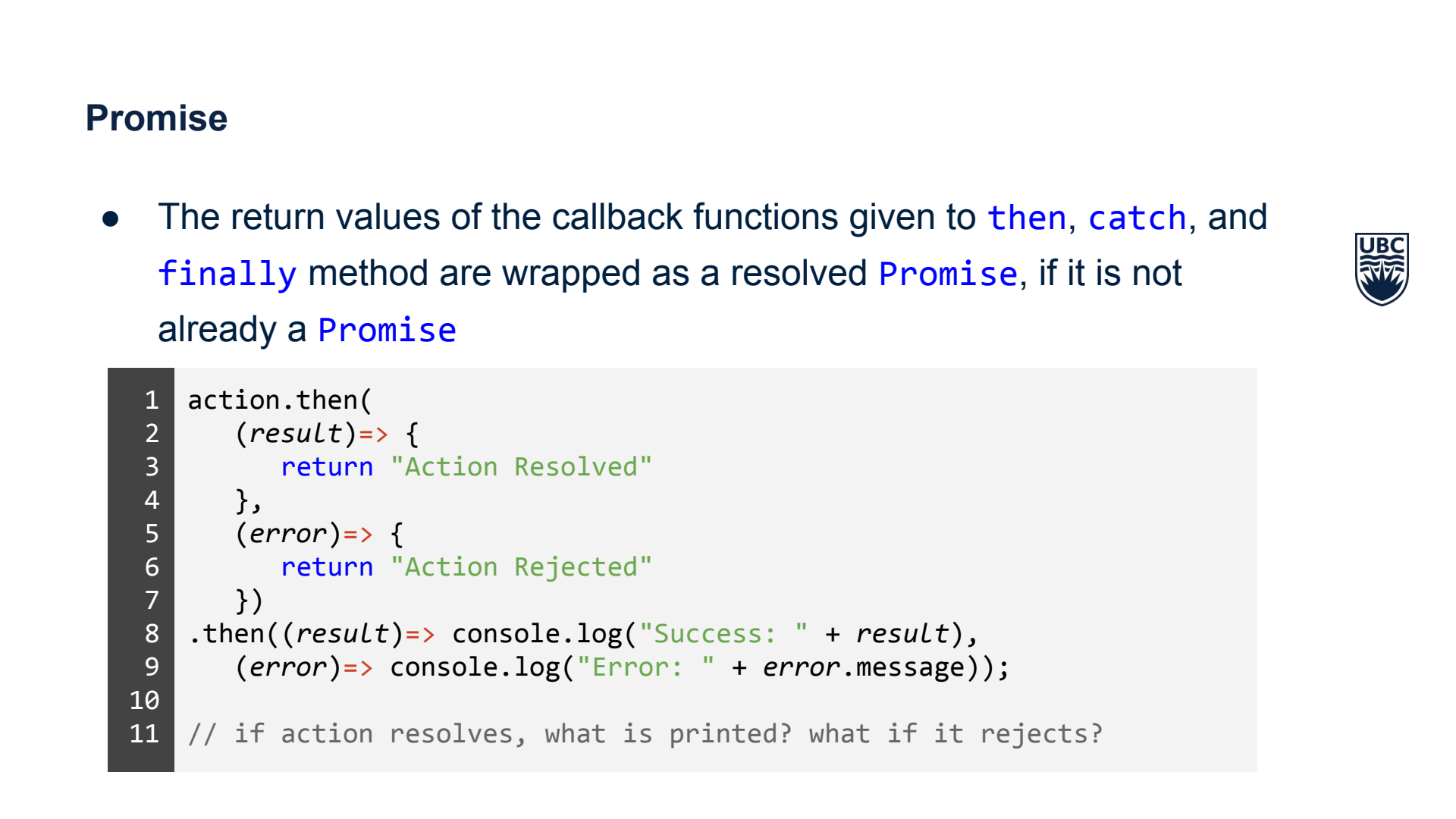
Promise

- The static functions `Promise.resolve` and `Promise.reject` are used to create a `Promise` object that immediately resolves or rejects with the given data
    - Useful when the next asynchronous operation expects a `Promise` object


```
action.then(
   (result)=> console.log(result), // result: "Success!"
   (error)=> console.log(error)    // error: Error("LowValueError")
)
.catch((err)=> console.log(err))
.finally(()=> console.log("The End!"));
```

Promise

- The return values of the callback functions given to `then`, `catch`, and `finally` method are wrapped as a resolved `Promise`, if it is not already a `Promise`

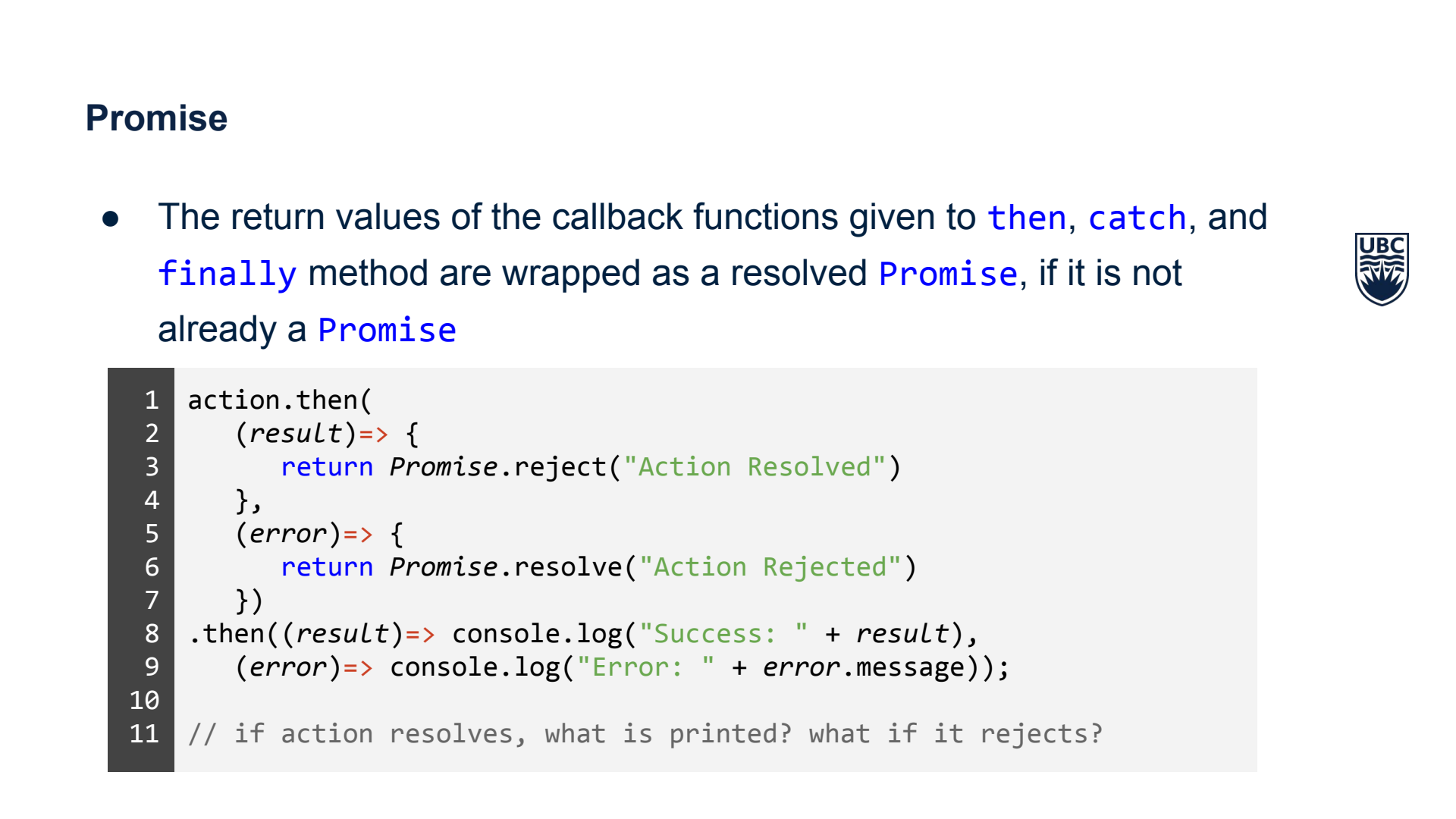


```
action.then(
   (result)=> {
      return "Action Resolved"
   },
   (error)=> {
      return "Action Rejected"
   })
.then((result)=> console.log("Success: " + result),
   (error)=> console.log("Error: " + error.message));

// if action resolves, what is printed? what if it rejects?
```

Promise

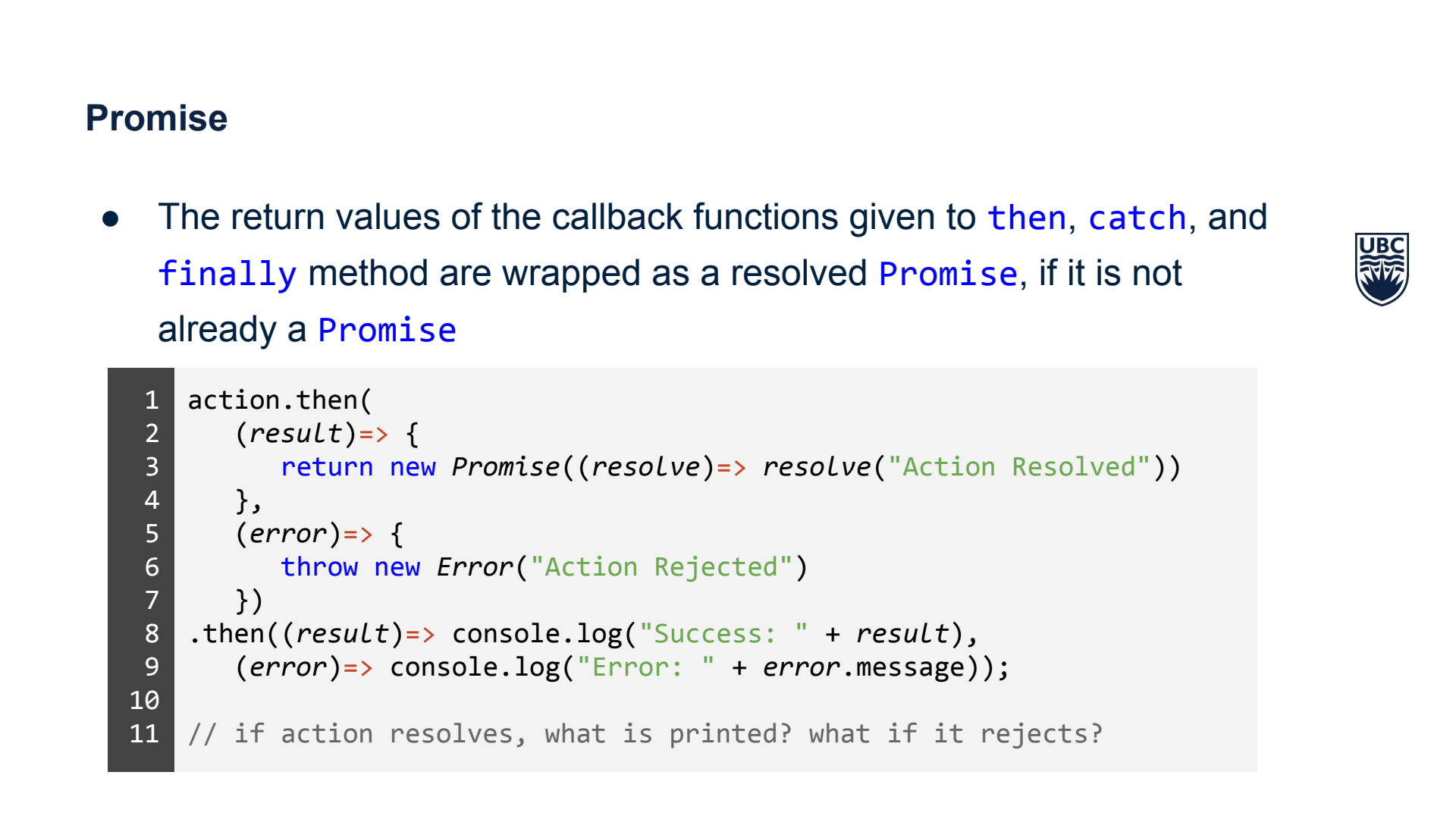
- The return values of the callback functions given to `then`, `catch`, and `finally` method are wrapped as a resolved `Promise`, if it is not already a `Promise`



```
1  action.then(
2     (result)=> {
3        return Promise.reject("Action Resolved")
4     },
5     (error)=> {
6        return Promise.resolve("Action Rejected")
7     })
8  .then((result)=> console.log("Success: " + result),
9     (error)=> console.log("Error: " + error.message));
10
11 // if action resolves, what is printed? what if it rejects?
```

Promise

- The return values of the callback functions given to `then`, `catch`, and `finally` method are wrapped as a resolved `Promise`, if it is not already a `Promise`



```
action.then(
   (result)=> {
      return new Promise((resolve)=> resolve("Action Resolved"))
   },
   (error)=> {
      throw new Error("Action Rejected")
   })
.then((result)=> console.log("Success: " + result),
   (error)=> console.log("Error: " + error.message));

// if action resolves, what is printed? what if it rejects?
```

Class Activity: Promisify

lectures/lecture-9/activity2.js

- Create a `readFile` function that wraps the Node.js `fs.readFile` function and provides a `Promise`-based interface
  - `function readFile(filepath)`
  - returns a `Promise` object that resolves to the file content, or rejects if error occurred

```
1  var fs = require("fs");    // you can use fs.readFile
2
3  function readFile (filepath){
4     // to implement
5  }
6
7  readFile("example.txt")
8  .then((result)=> console.log(result.length))
9  .catch((error)=> console.log(error));
10
```

Promise

- Using the static function `Promise.all`, we can wait for multiple concurrent `Promise`s to be resolved (sort of like joining threads)
  - `Promise.all` accepts an Array of promises and returns a `Promise` that resolves to an array of results (in the same order as the promises given)

```
1  var multi = Promise.all([
2     new Promise((resolve)=> setTimeout(()=> resolve("A"), 2000)),
3     new Promise((resolve)=> setTimeout(()=> resolve("B"), 3000)),
4     new Promise((resolve)=> setTimeout(()=> resolve("C"), 1000)),
5  ]);
6
7  multi.then(
8     (results)=> console.log(results),
9     (error)=> console.log(error));
10
```

Promise

- Using the static function `Promise.race`, we can retrieve the first `Promise` to resolve out of a set of concurrent `Promises`
    - `Promise.race` accepts an Array of promises and returns the first `Promise` that resolves

```
1  var multi = Promise.race([
2     new Promise((resolve)=> setTimeout(()=> resolve("A"), 2000)),
3     new Promise((resolve)=> setTimeout(()=> resolve("B"), 3000)),
4     new Promise((resolve)=> setTimeout(()=> resolve("C"), 1000)),
5  ]);
6
7  multi.then(
8     (result)=> console.log(result),
9     (error)=> console.log(error));
10
```

Asynchronous Programming with Promises

1. What is a Promise
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3. **Asynchronous Programming with Promises**

Asynchronous Programming

- JavaScript involves a lot of asynchronous operations
  - The Internet is where JavaScript is used: this involves a lot of **AJAX requests**
  - The **I/O model** for the JavaScript VM is **asynchronous**: files, sockets, processes, Inter-process communication, and I/O streams all handled by **asynchronous API**
- The `Promise` API makes it easy to compose a sequence of asynchronous operations as a dataflow pipeline

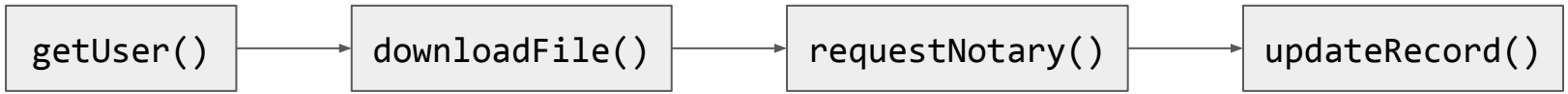
Asynchronous Programming

Scenario 1: Node.js application providing a document signing service

- This fictional app will take a user-specified file, request a certified authority to digitally sign the file, and return the signed file to the user
  a. Read user identity from the database
  b. Read the file data from a remote storage
  c. Send the user identity and file to a private digital signing service
  d. Receive the result and update the database
  e. Return the result to the user

Asynchronous Programming

Scenario 1: Node.js application providing a document signing service



Asynchronous Programming

Scenario 1: Node.js application providing a document signing service

```
1  function signDocument(userID, fileURL){
2     return getUser(userID)
3        .then((user)=> downloadFile(fileURL, user.apiKey))
4        .then((file)=> requestNotary(file, user.cert))
5        .then((signed)=> updateRecord(userID, signed.hash))
6        .then(()=> (true), (err)=> Promise.reject(err))
7  }
8
9  var app = express();
10 app.post("/sign-request", (req, res)=> {
11    signDocument(req.session.username, req.body.fileURL)
12     .then(()=> res.status(200).send("Successful"))
13     .catch((err)=> res.status(500).send("Server Error"))
14 });
```

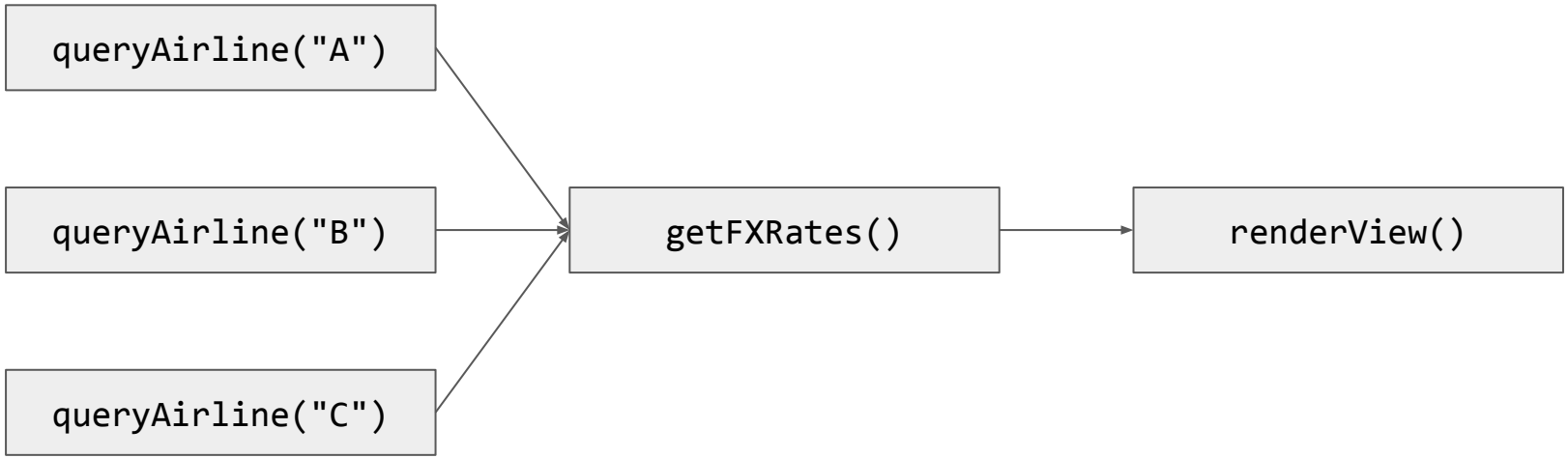
Asynchronous Programming

Scenario 2: Browser application using multiple web services

- This fictional app searches airplane tickets, compares their prices, and provides sales online
  a. Make requests to different airline websites to retrieve price and schedule
  b. Make request to a foreign exchange API to provide price in local currency
  c. Dynamically render HTML to ask user to select a ticket

Asynchronous Programming

Scenario 2: Browser application using multiple web services



Asynchronous Programming

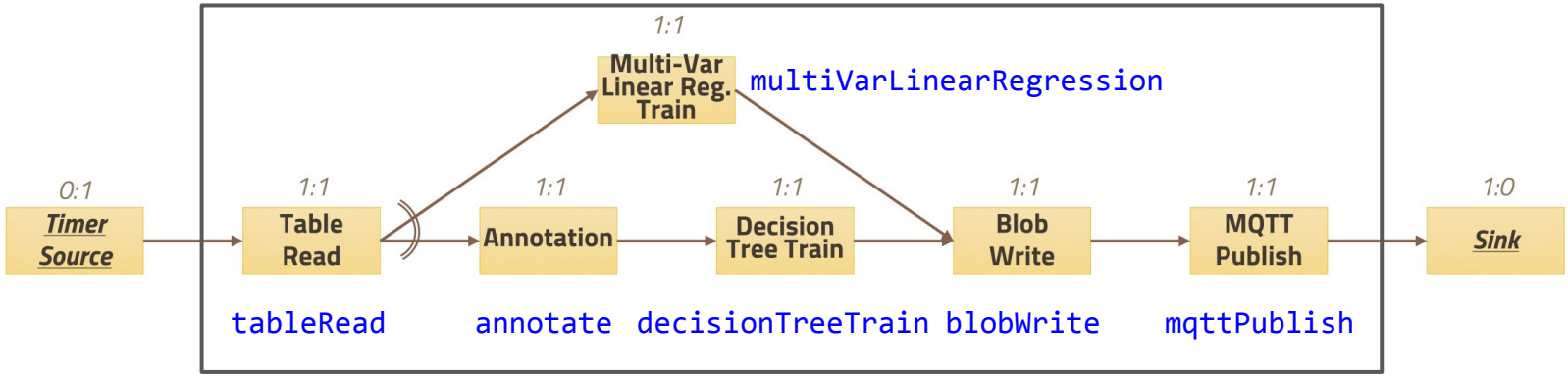
Scenario 2: Browser application using multiple web services

```
1  function searchTickets(query){
2     return Promise.all([
3           queryAirline("A", query),
4           queryAirline("B", query),
5           queryAirline("C", query),
6        ])
7        .then((results)=> {
8           return getFXRates()
9           .then((rates)=> convertCurrency(results, rates))
10       })
11       .then((data)=> renderView(data))
12 }
13 var btn = document.getElementById("search-btn");
14 btn.addEventListener("click", (e)=> searchTickets(query));
```

Class Activity: Dataflow Programming

lectures/lecture-9/activity3.js

- Consider the following dataflow diagram, assuming each component is available as a `Promise`-based function
  - Assume all functions have the signature `function(arg)`



- Create a `trainModel` function that wraps the entire benchmark as a `Promise`-based function