

SEBA Master: Web Application Engineering

Developing Single-Page Applications with a Specific Web Application Framework (React)

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5. Developing Single-Page Applications with a Specific Web Application Framework (React)

- Web Application Framework Comparison
- Basic Concepts of the Chosen Framework
- State Management
- Navigation & Routing
- Client-Server Communication
- Consuming RESTful Service


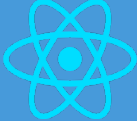

Web application frameworks for the client side help developers to

- **Solve recurring problems:**
 - Rendering of content and layout
 - User interaction and re-rendering
 - Validation of user input
 - Error message handling
 - Localization and internationalization
 - Personalization, user & session management
 - Navigation
 - Support of different devices
- **Structure code in a scalable, extensible and re-usable way**
- **Facilitate documentation**
- **Improve security**

Some web application frameworks also support the implementation of recurring business requirements, for example search engine optimization (SEO) or user tracking - often through community extensions.

Early web application frameworks have a focus on structuring content and layout (HTML, CSS, JS).
Current frameworks put more emphasis on structuring behavior (state management, updates & re-rendering)

Web Application Framework Comparison for the Client-side (JavaScript)

	Angular 5 	React 16 	Vue 2 
Application architecture	Components	Components	MVVM
Stability	Disruptive API changes from AngularJS to Angular	Robust API	Robust API
Community	Divided between AngularJS and Angular	Active	Active
Backed by company	Google	Facebook	-
Support for native applications (iOS, Android)	NativeScript	React Native	NativeScript
Server-side rendering	supported	supported	supported

History of React



Created by Jordan Walke as a JavaScript port of XHP (HTML component framework for PHP) at Facebook

Used for Facebook Newsfeed

Used for Instagram

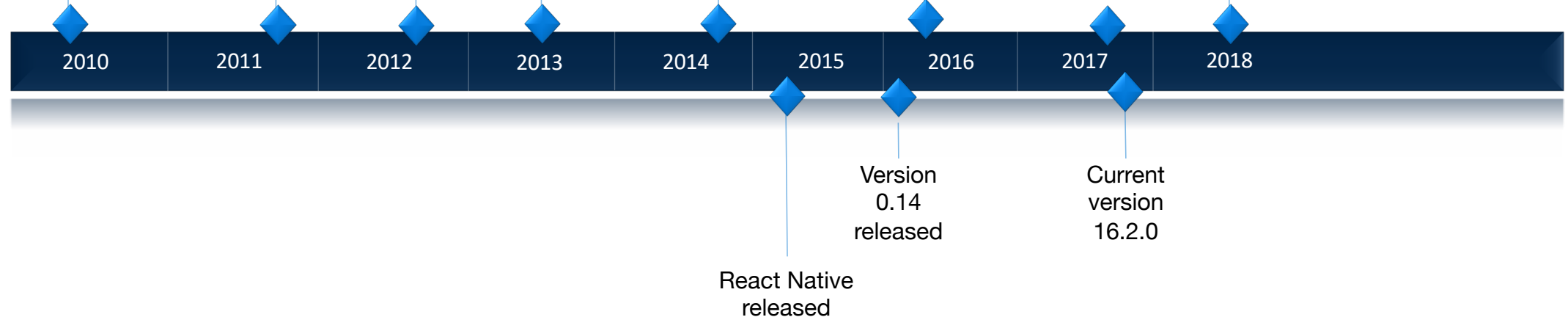
Open sourced with Apache license, version 0.3.0

License change to BSD with additional *license withdrawal* clause, Version 0.10.0

Version 15.0 released

Change to MIT license, version 16.0

React Fiber announced (new core algorithm)



Version 0.14 released

Current version 16.2.0

Introduction to React

- Open source frontend JavaScript library
- First stable release in July 2013
- Current stable version: 16.8.4 (**should be used in exercises**)
- Currently, one of the most popular JavaScript frameworks besides Angular and VueJS
- Used by many companies, e.g. Facebook, AirBnB, Amazon, Paypal, cf.
<https://github.com/facebook/react/wiki/sites-using-react>
- Note: The **concept of a component-based architecture is independent of a concrete framework, e.g. React or Angular.**

Motivation for the development of React

- Support maintainability and scalability of large-scale web applications
- Focus on user interface aspects only (no commitment to specific client/server communication)
- Strictly component-based frontend applications, state is managed in components
- VirtualDOM rendering mechanism and using functional programming concepts improves testability
- A vivid developer ecosystem (e.g. providing the powerful create-react-app node module that allows live-editing and benefits from the NodeJS ecosystem)

Concept	Description
Component	A component is a logical encapsulation of (potentially complex) user interface elements that can be reused and nested.
VirtualDOM	The VirtualDOM is an abstraction layer of the the DOM used by React to minimize the (costly) operations on the document object model (DOM) using DOM Diffing.
State	State describes data objects that are managed within a component. The data objects are mostly altered by user actions.
Props	Props are immutable state objects received from a parent component. A component composes and sends props to its child components.
JSX	An extension to ECMAScript that enables the definition of XML/HTML in ECMAScript. It requires a preprocessor (transpiler) to transform JSX to JavaScript, which also allows to evaluate JavaScript expressions during the transformation process.
Router	Functionality provided by libraries/frameworks to facilitate navigation on a web site, here in particular among pages of a single-page web application.

Simple “Hello World” Example

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<https://codepen.io/sebischair/pen/aYrGog>

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9. Access the components state, in particular a variable name using JavaScript expressions
10. Invoke React to render the component „Hello“ to the div with id='root'
11. Once defined, components can be reused multiple times.

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23     ReactDOM.render(<div><Hello name='World' />
24                       <Hello name='SEBA' /></div>,
25                       document.getElementById('root')
26                     )
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```

JavaScript XML (JSX)

JSX

- is an XML-like extension to ECMAScript without any defined semantics
- requires a transpiler to convert JSX to JavaScript
- has a syntax similar to E4X Specification (ECMA-357)
- allows to embed HTML code in Javascript:

```
return (<h1>Hello World</h1>)
```

- requires a single root element, i.e. the following example does **not** work:

```
return (<h1>Hello World</h1><h1>Hello universe</h1>)
```

- requires developers to declare standard HTML attributes in a JSX-specific syntax:

```
return (<h1 className='title'>Hello World</h1>)
```

- With React, ES6 template literals are often used in JSX to access state and props variables:

```
return (<h1>Hello ${this.props.name}</h1>)
```

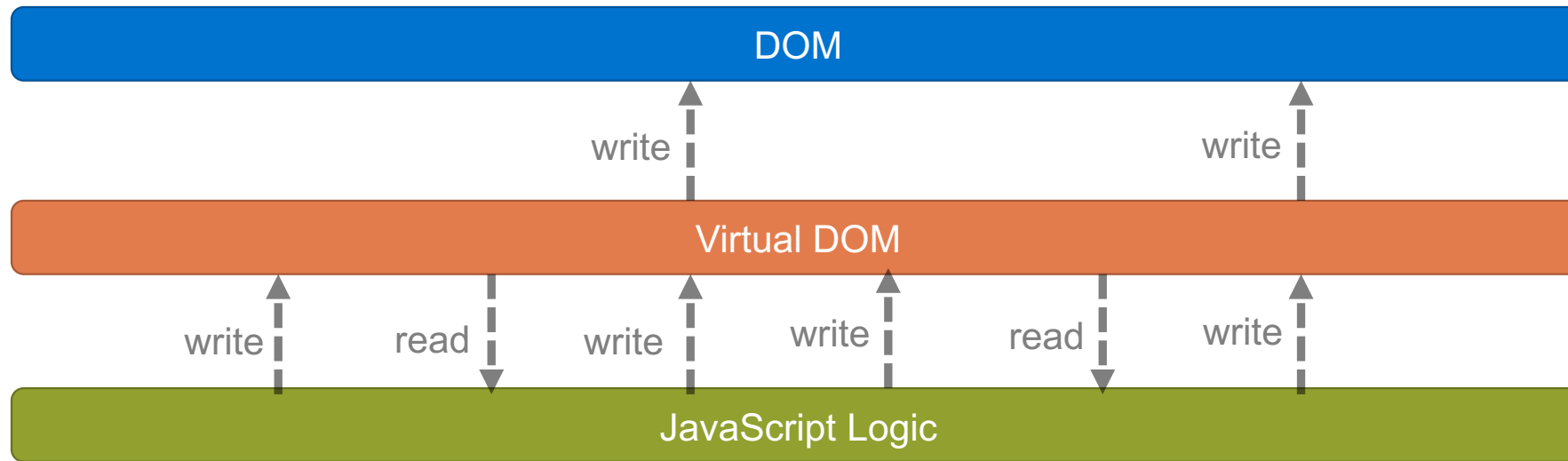
- The JSX spread operator addresses all properties of an object with arbitrary many properties:

```
let props = {foo: 'x', bar: 'y'}; let c = <Component {...props} />;  
console.log(c.foo); /* 'x' */ console.log(c.bar); /* 'y' */
```

<http://facebook.github.io/jsx/>

<https://reactjs.org/docs/jsx-in-depth.html>

<http://www.ecma-international.org/publications/files/ECMA-ST-WITHDRAWN/Ecma-357.pdf>



- A general rule of thumb is that DOM operations are costly, especially in large applications
- React creates a lightweight in-memory data structure (Virtual DOM) that represents the DOM that is used to minimize the number of DOM operations:
 1. Eliminate read operations on the DOM
 2. Update only elements that actually changed (DOM Diffing)
- An element (for example a component) can be added to the Virtual DOM with the `React.createElement(type, [props], ...)` method
- If ES6 classes are used to create components, `createElement` methods are called automatically

- The Virtual DOM is, like the DOM, a tree structure
 - React minimizes re-render/write operations to the DOM by identifying changed elements in the VirtualDOM
 - Therefore, an old Virtual DOM tree is compared to a Virtual DOM tree where all updates have been applied
 - Comparing two trees has a complexity of $O(N^3)$, where N is the number of nodes of the larger of the two trees.
-
- React's diffing algorithm implements a heuristic that recursively identifies changed elements in $O(N)$
 - The diffing algorithm recursively walks over the trees top-down and identifies changed components.
 - For a particular component, React differentiates between changes of component type, attributes, style and state and identifies the minimal necessary updates to the DOM
 - The concept of immutable state objects helps the Diffing algorithm to efficiently detect changed states
 - Developers can optimize the heuristic by manually specifying if an element has or has not to be updated (e.g. defining `shouldComponentUpdate()`)

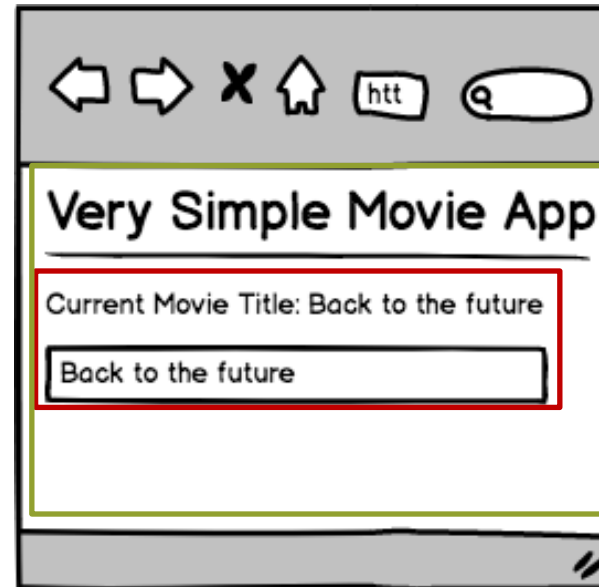
What is a React Component?

- React components are used to split the UI into re-usable pieces.
- Components can be nested, i.e. they are organized in a hierarchy
- Components encapsulate state
- Components are the core concept of a component-based web application architecture
- See the official documentation: <https://reactjs.org/docs/react-component.html>

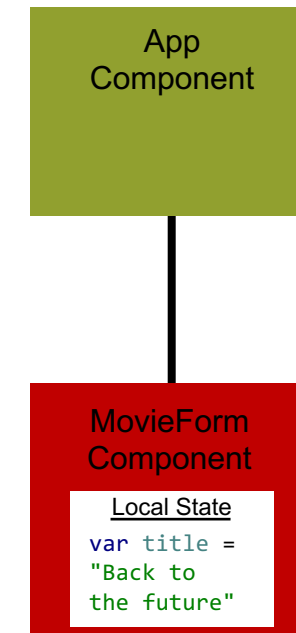
React Components & State Management Problems (1)

- The “Very Simple Movie App” contains a simple input field where a user can change the title of a single movie. The Very Simple Movie App displays the title as currently entered in the input field.
- From the mockups we identify two components: The App Component that represents the full application. It contains a MovieForm Component that handles the form.

View:



Component Hierarchy:



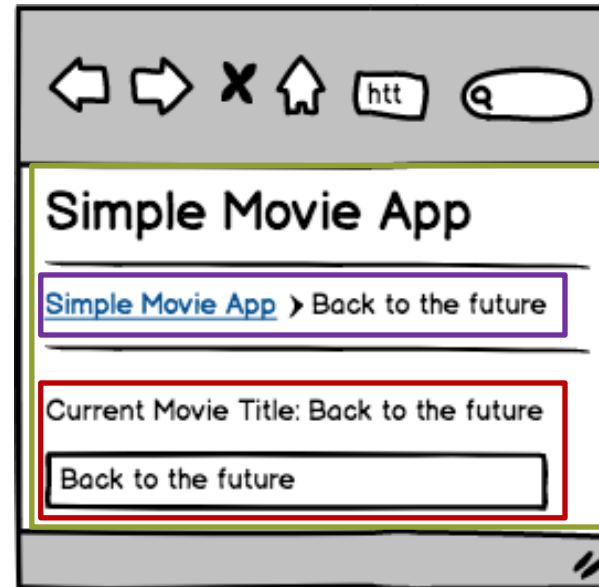
State:

In this simple case the MovieForm component encapsulates its own state and does not depend on other components.

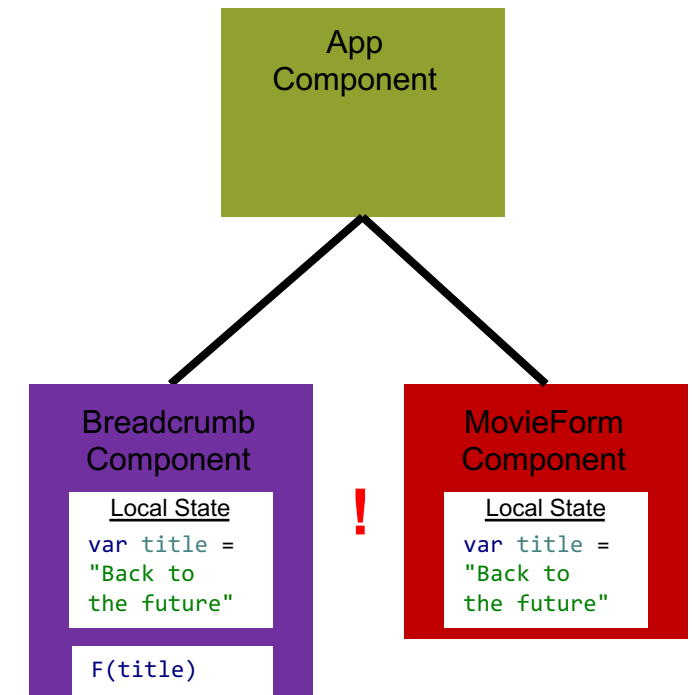
React Components & State Management Problems (2)

- In contrast to the previous “Very Simple Movie App”, the “Simple Movie App” additionally contains a breadcrumb element that instantly changes with the user input in the MovieForm component.
- We identify the visual breadcrumb element as another component: the Breadcrumb Component.

View:



Component Hierarchy:



State:

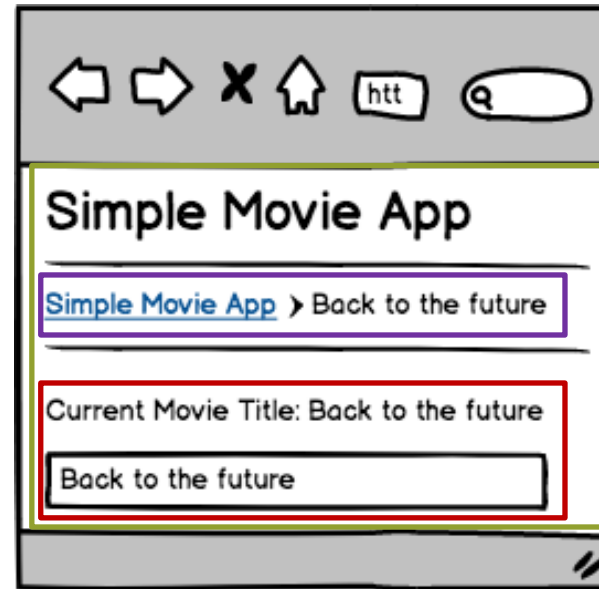
In this more complex case, a component (or DOM element) depends on the state of another component: Whenever the Breadcrumb Component performs an operation `F(title)` on the title variable (e.g. to display the variable's content), it requires the current value of the title variable in the MovieForm Component.

<https://codepen.io/sebischair/pen/PRvePY>

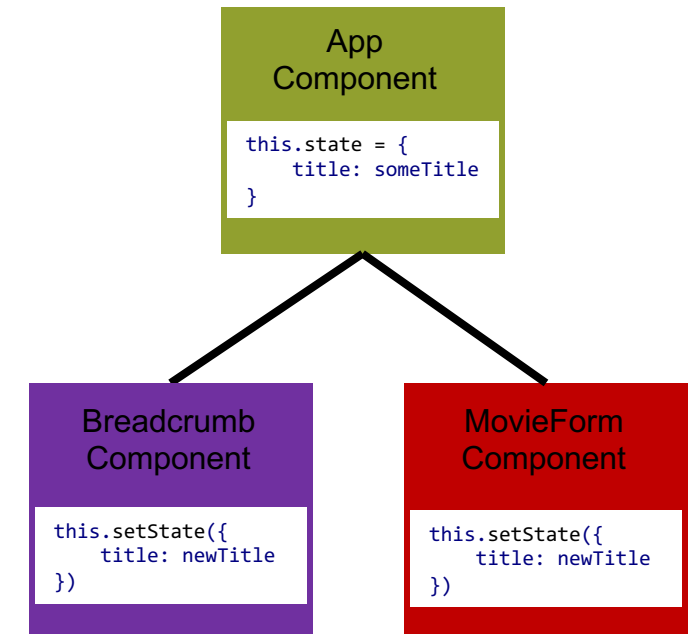
React Solution to State Management Problems (1)

- Components encapsulate state
- The state is stored in immutable JavaScript objects
- Similar to the functional programming paradigm, only new/copies of state objects are created
- A component's state is assigned once in the constructor of a component and state updates are carried out via the `setState(newStateObject)` method of React components that gets passed a new state object as a parameter rather than manipulating the state object directly
- State is strictly passed down in the component hierarchy

View:



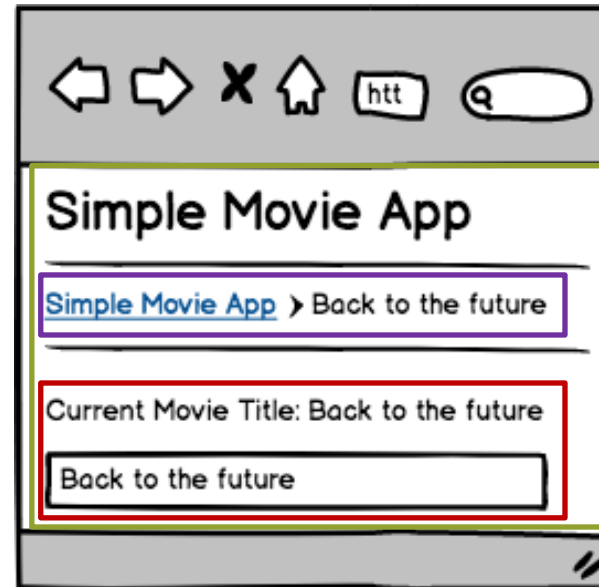
Component Hierarchy:



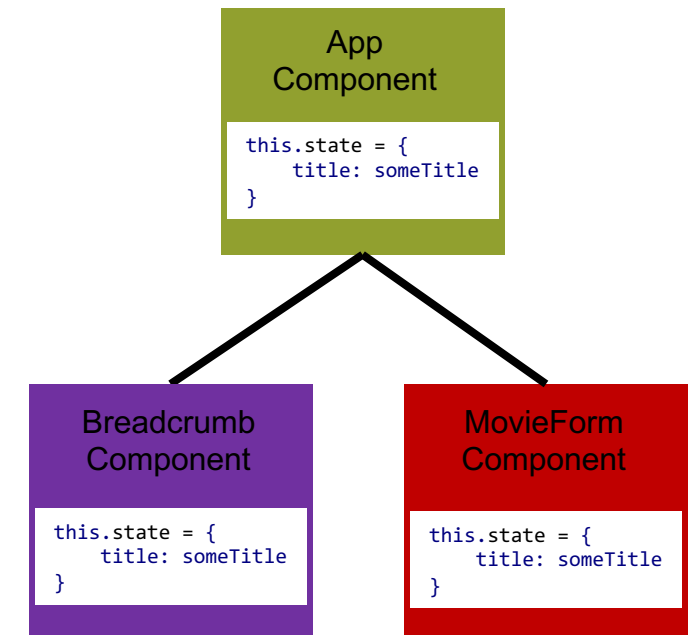
React Solution to State Management Problems (2)

- A core concept of React is to **handle state in the closest common ancestor component**, when components depend on the state of other components.
- When the Breadcrumb component is added to the "Very Simple Movie App" example, the App Component can be identified as the closest common ancestor component of the MovieForm and the Breadcrumb Components.
- Therefore, the title state should be handled in the App Component.
- In React terminology this process is called "lifting state up".
- This requires a few changes in all three components that we will go through step by step in the following slides together with a selection of React concepts.

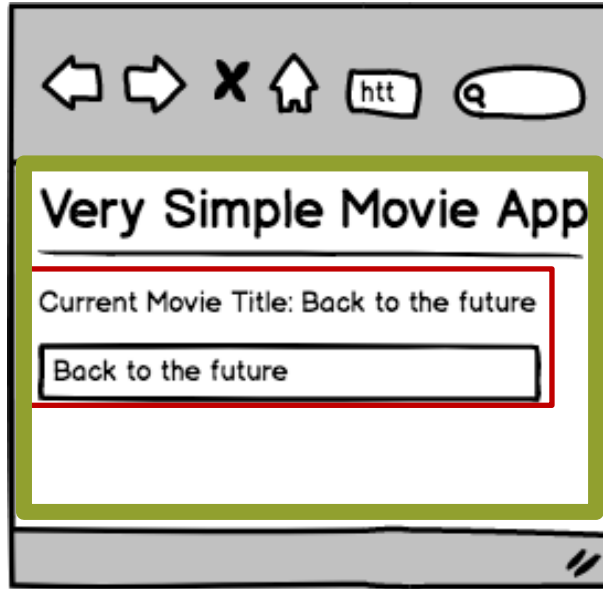
View:



Component Hierarchy:



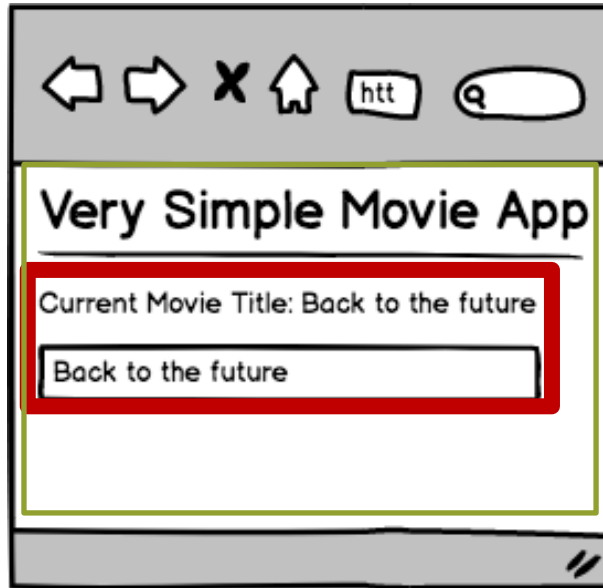
The Source Code for the Very Simple Movie App (1)



```
class App extends React.Component {  
  constructor() {  
    super();  
  }  
  
  render() {  
    return (  
      <div>  
        <h1>Very Simple Movie App</h1>  
        <hr/>  
        <MovieForm title="Back to the Future" />  
      </div>  
    );  
  }  
}
```

- The App Component is defined as a standard ES6 class. In React this is called a **class component**.
- Information is propagated down the component hierarchy: Here, a string with a default movie title is a **parameter** to the MovieForm component.

The Source Code for the Very Simple Movie App (2)

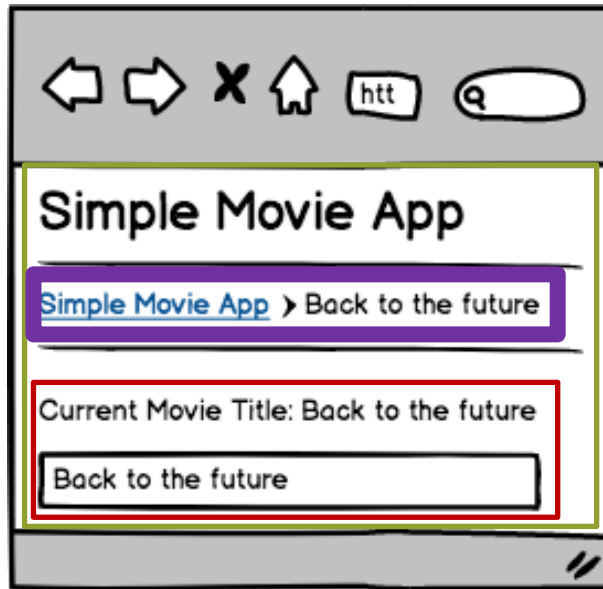


- The MovieForm Component receives information from the parent App Component in a variable typically called **props** and the local state is initialized.
- The MovieForm is a so-called **controlled component**, i.e. the form input is synchronized with the component's state. Note that the event handler function needs to be bound in the constructor

```
class MovieForm extends React.Component {  
  constructor(props) {  
    super(props);  
    this.state = {  
      title: props.title  
    };  
    this.handleChange = this.handleChange.bind(this);  
  }  
  handleChange(event) {  
    this.setState({  
      title: event.target.value  
    });  
  }  
  render() {  
    return (  
      <form>  
        <p>  
          <b>Current movie title:</b>  
            {this.state.title}  
        </p>  
        <fieldset>  
          <legend>Enter movie title:</legend>  
          <input type="text"  
            value={this.state.title} onChange={this.handleChange} />  
        </fieldset>  
      </form>  
    );  
  }  
}
```

<https://codepen.io/sebischair/pen/dmEePg>
<https://reactjs.org/docs/lifting-state-up.html>

Adding a Breadcrumb Component – The Simple Movie App (1)



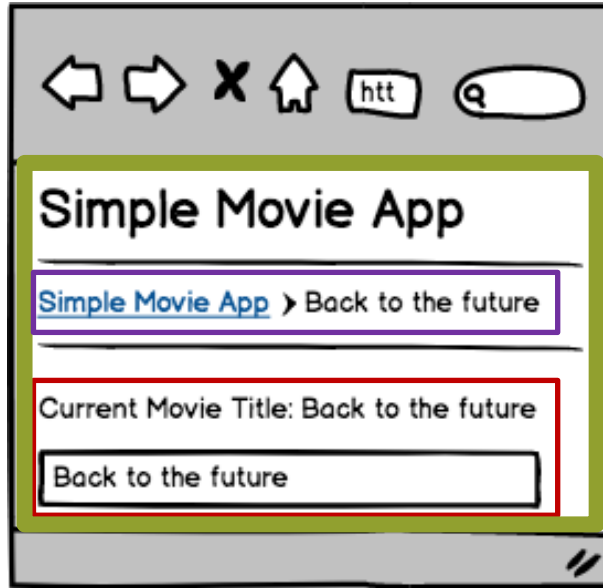
```
ReactDOM.render(  
  <App title="Back to the Future" />,  
  document.getElementById('root')  
);
```

- First, we move the default title configuration so that the App Component receives the default title as a parameter. While not required for lifting the state up, this simplifies a structured explanation.
- We also add a Breadcrumb Component that displays the current title. It is a so-called **functional component** defined as a function.

```
function Breadcrumb(props) {  
  return <span>  
    <b>Simple Movie App</b>  
    > {props.title}  
  </span>;  
}
```

<https://codepen.io/sebischair/pen/PRvePY>
<https://reactjs.org/docs/lifting-state-up.html>

Adding a Breadcrumb Component – The Simple Movie App (2)



- The state handling of the title is moved from the MovieForm Component now to the parental App Component. It receives the default title from above.
- The handler function for state updates is moved also up to the App Component
- The Breadcrumb Component is added to the App Component and gets passed down the title
- The title now gets passed down to the MovieForm Component together with the callback handler

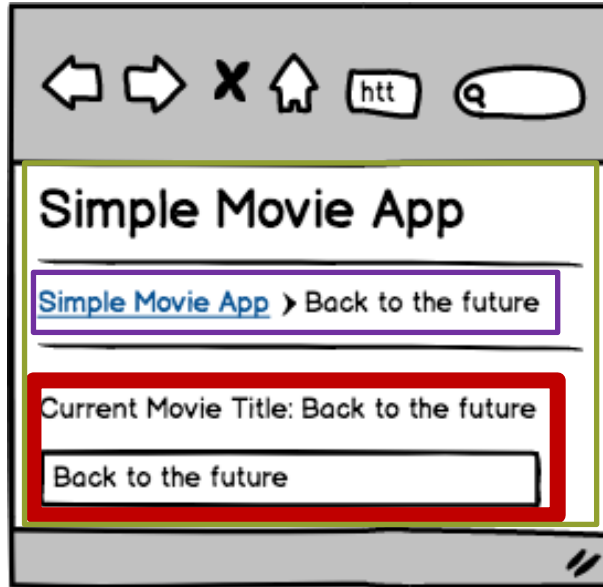
```
class App extends React.Component {
  constructor(props) {
    super(props);
    this.state = {
      title: props.title
    };
    this.handleClick =
      this.handleClick.bind(this)
  }

  handleClick(event) {
    this.setState({title: event.target.value});
  }

  render() {
    return (
      <div>
        <h1>Simple Movie App</h1>
        <hr/>
        <Breadcrumb title={this.state.title}/>
        <hr/>
        <MovieForm title={this.state.title}
          onChange={this.handleClick}/>
      </div>
    );
  }
}
```

<https://codepen.io/sebischair/pen/PRvePY>
<https://reactjs.org/docs/lifting-state-up.html>

Adding a Breadcrumb Component – The Simple Movie App (3)



- The MovieForm Component now receives the title from the parental App Component as props.
- Title changes are handled by the **callback handler** function received from the parental App Component.
- The title variable is now accessed via the props member variable rather than the local state member variable!

```
class MovieForm extends React.Component {  
  constructor(props) {  
    super(props);  
    this.handleChange = this.handleChange.bind(this)  
  }  
  
  handleChange(e) {  
    this.props.onTitleChange(e)  
  }  
  
  render() {  
    return (  
      <form>  
        <p>  
          <b>Current movie title:</b>  
          {this.props.title}  
        </p>  
        <fieldset>  
          <legend>Enter movie title:</legend>  
          <input type="text"  
            value={this.props.title}  
            onChange={this.handleChange} />  
        </fieldset>  
      </form>  
    );  
  }  
}
```

<https://codepen.io/sebischair/pen/PRvePY>
<https://reactjs.org/docs/lifting-state-up.html>

Typechecking: PropTypes

- Type-checking can help to prevent bugs in larger applications
- Type-checking can be achieved by using TypeScript or **React's built-in PropTypes**.

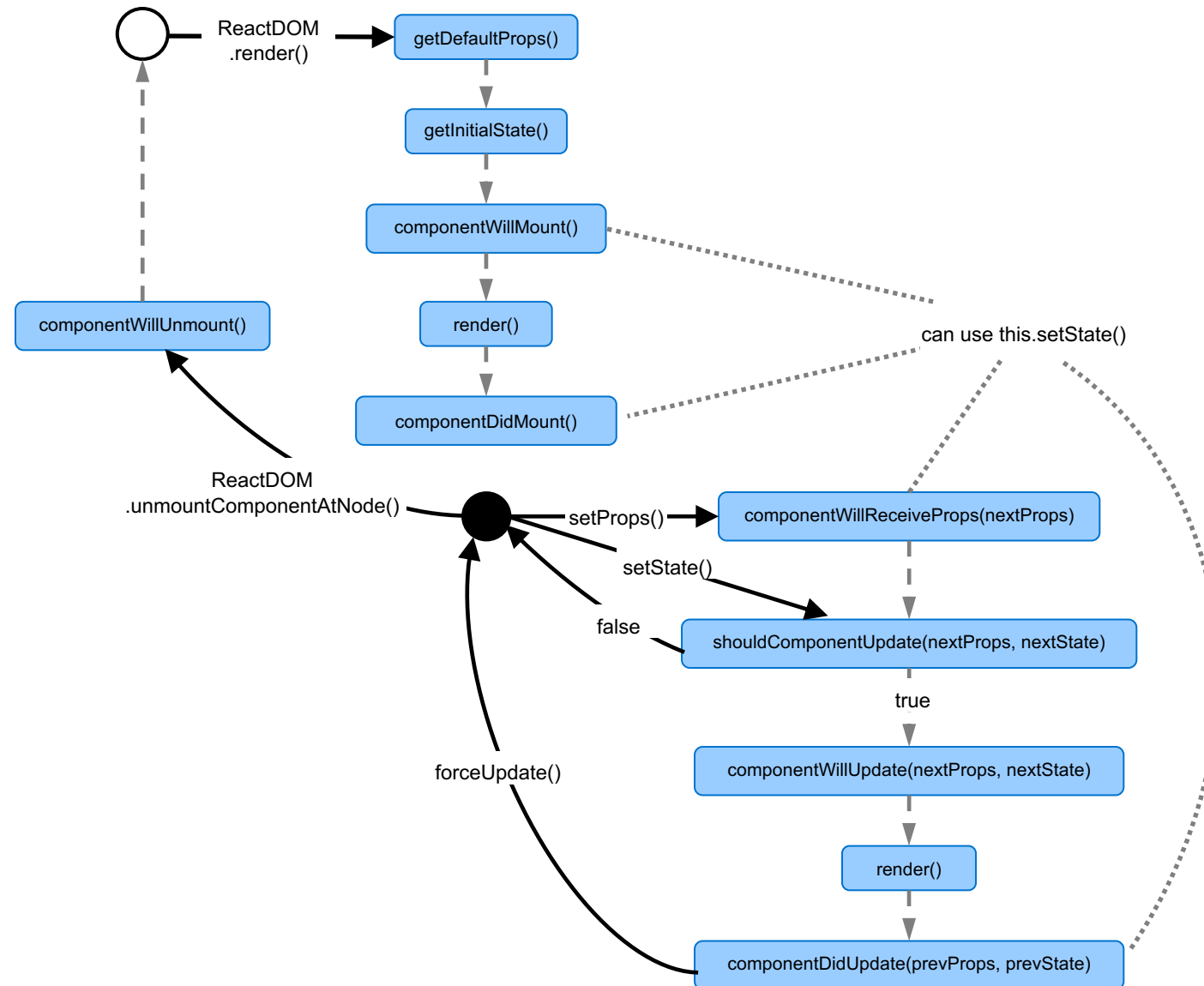
```
import PropTypes from 'prop-types';

class MovieForm extends React.Component {
  constructor(props) {
    super(props);
    ...
  }
  ...
  render() {
    return (
      <form>
        <p>
          <b>Current movie title:</b>
          {this.props.title}
        </p>
        ...
      </form>
    );
  }
}

MovieForm.propTypes = {
  title: PropTypes.string.isRequired
};
```

<https://reactjs.org/docs/typechecking-with-proptypes.html>

React Component Lifecycle



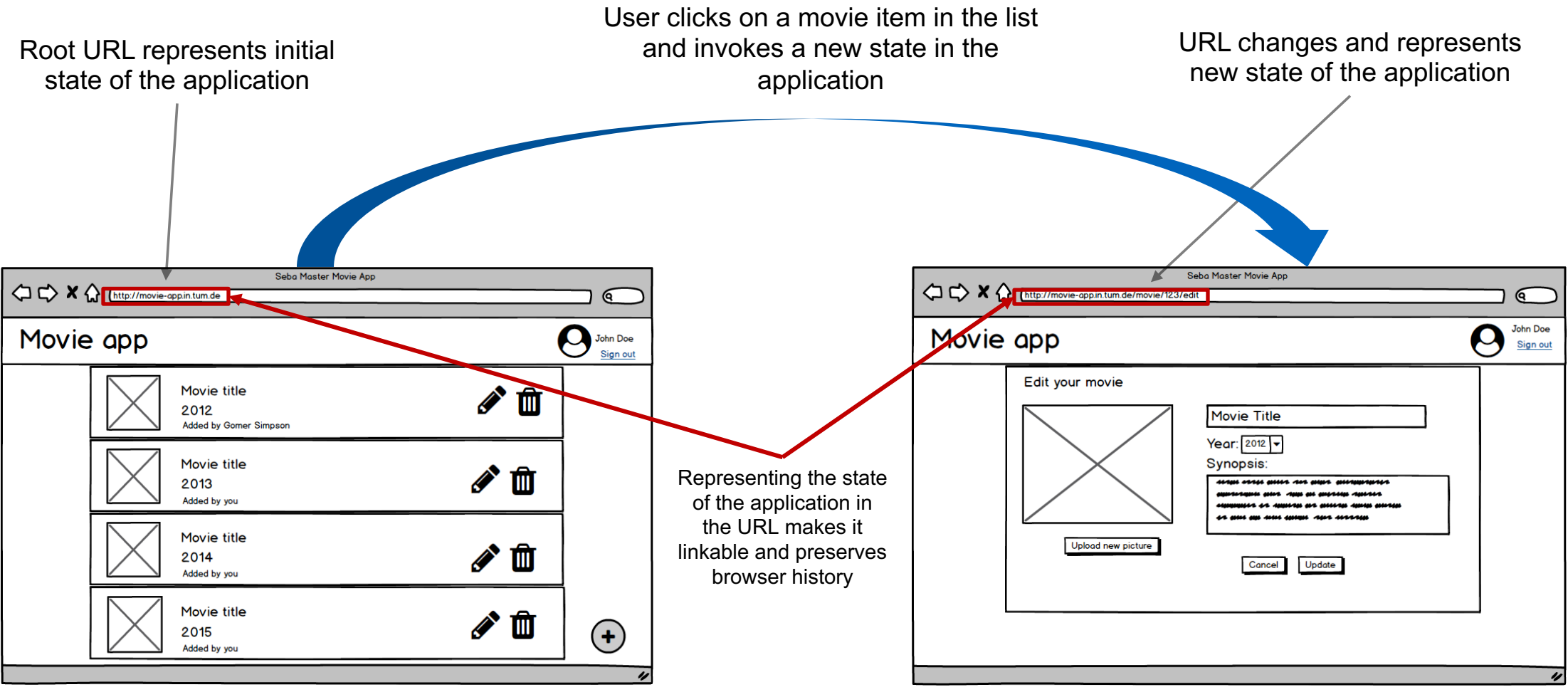
Classic navigation behavior of a browser

- The URL entered in the browsers' address bar reflects the current address of a website in the internet
- The URL can be seen as the current state of the browser
- Usually, users navigate from one page to another by clicking a hyperlink
- Each sub-page has its own unique link
- The browser offers controls to navigate back and forth in the history

Challenges for Single-Page applications

- New content is loaded via asynchronous API calls and a state change by URL is not necessary
- How to control and preserve the browser history for Ajax applications?
- How to manage states?
- How to make SPAs “linkable”?

React Navigation & Routing (2)



Movie App Routing Example (Via react-router Package)

```
class App extends React.Component {
  constructor(props) {
    ...
    this.state = {
      title: 'Movie Example App',
      routes: [
        {component: MovieListView, path: '/', exact: true},
        {component: MovieDetailView, path: '/show/:id'},
        ...
      ]
    }
  }
  render() {
    return (
      <div>
        <Router>
          <Switch>
            {this.state.routes.map((route, i) =>
              (<Route key={i} {...route}/>))}
          </Switch>
        </Router>
      </div>
    );
  }
}
```

Routes are configured as a state object in the App Component

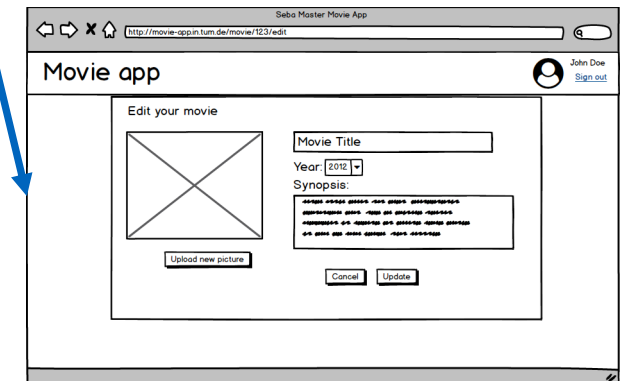
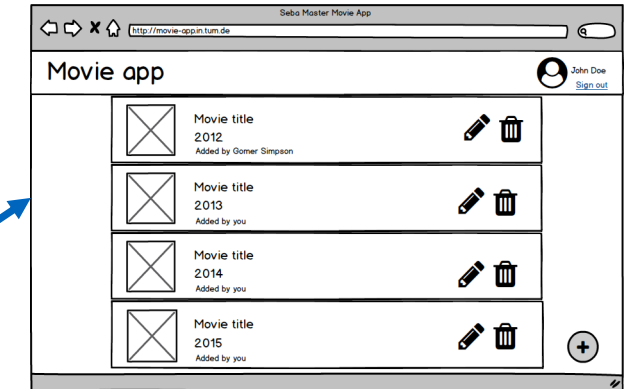
The render function for this App Component performs the loading of the configured components for the Routes

Adding links in (sub-) components

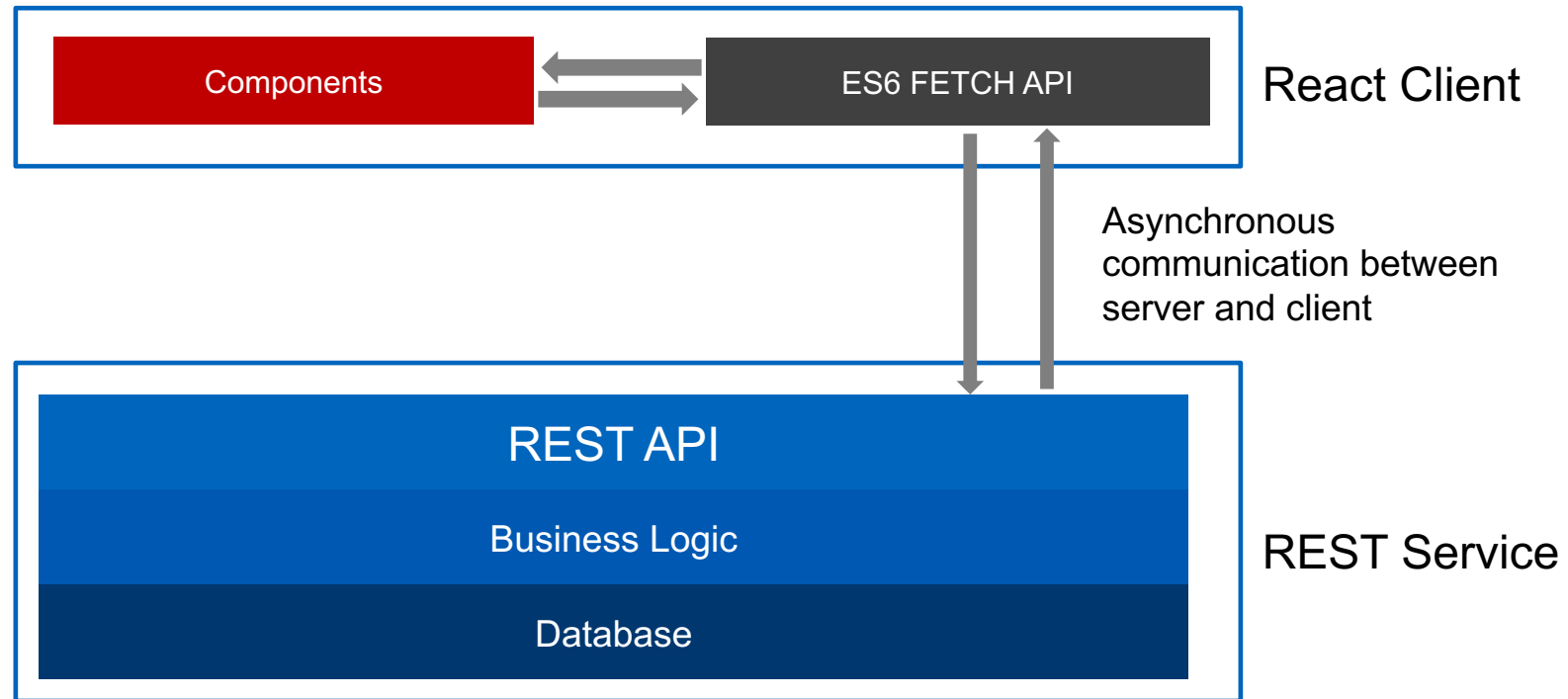
```
<Link to={'/'}>Home</Link>
<Link to={`/show/${this.props.movie._id}`}>Link to movie {this.props.movie.title}</Link>
```

Route for MovieList View, default route

Route for Movie Detail View with parameter movie id



Consuming RESTful Services in React Applications and ES6



The ES6 standard provides a FETCH API that provides a global `fetch()` method to consume REST services.

Client-Server Communication

The ES6 FETCH API

- The FETCH API provides a standardized API to perform network requests.
- The FETCH API is supported by all modern browsers (except Internet Explorer).
- In contrast to former XMLHttpRequest calls, the fetch API uses promises (see Chapter 04).
- In contrast to the jQuery implementations of promises, server status codes need to be checked manually.

Via the fetch API requests can be configured regarding type, headers, cookies etc.

success_function:
Note that HTTP Status codes need to be checked

error_function, e.g. socket error, timeout, ...

```
fetch(url, {  
  method: 'GET',  
  headers: header  
}).then((response) => {  
  if(response.ok) {  
    console.log(response.json());  
    /* work with data */  
  }  
  else {  
    console.log(response.status);  
    /* an error occurred */  
  }  
}).catch((e) => {  
  console.log(e);  
});
```

Using Services to Consume REST Data

It is not required by React, but we recommend to encapsulate API **Services** in React to **share code and functionality** across an application.

A service is used to separate the actual data from the components.

We recommend to use the following guidelines:

- Services are only instantiated when a component depends on it (**lazy loading**)
- Services are instantiated as **singletons**

Separating Generic Services & API-specific Services

- It is a good practice to factor out code that frequently changes and to separate it from code that is stable for a long time

```
class HttpService {
  static get('http://localhost:3000/movies',
            onSuccess, onError) {
    let header = new Headers();
    fetch(url, {
      method: 'GET',
      headers: header
    }).then((resp) => {
      if(resp.ok) {
        return resp.json();
      }
      else {
        resp.json().then((json) => {
          onError(json.error);
        });
      }
    }).then((resp) => {
      onSuccess(resp);
    }).catch((e) => {
      onError(e.message);
    });
  }
}
```

```
import HttpService from './HttpService';

class MovieService {

  static getMovie(id) {
    return new Promise((resolve, reject) => {
      HttpService.get('http://localhost:3000/movies/${id}', function(data) {
        if(data != undefined || Object.keys(data).length != 0) {
          resolve(data);
        }
        else {
          reject('Error while retrieving movie');
        }
      }, function(textStatus) {
        reject(textStatus);
      });
    });
  }
}
```