

JavaScript Front-End Web App Tutorial Part 3: Dealing with Enumerations

**Learn how to build a front-end
web application with enumeration
attributes, using plain JavaScript**

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JavaScript Front-End Web App Tutorial Part 3: Dealing with Enumerations: Learn how to build a front-end web application with enumeration attributes, using plain JavaScript

by Gerd Wagner

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This tutorial is also available in the following formats: PDF [[enumeration-tutorial.pdf](#)]. You may run the example app [[3-EnumerationApp/index.html](#)] from our server, or download it as a ZIP archive file [[3-EnumerationApp.zip](#)]. See also our project page [<http://web-engineering.info/>].

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Foreword

This tutorial is Part 3 of our series of six tutorials [<http://web-engineering.info/JsFrontendApp>] about model-based development of front-end web applications with plain JavaScript. It shows how to build a web app where model classes have enumeration attributes.

The app supports the four standard data management operations (**Create/Read/Update/Delete**). The other parts of the tutorial are:

- Part 1 [<http://web-engineering.info/tech/JsFrontendApp/minimal-tutorial.html>]: Building a **minimal** app.
- Part 2 [<http://web-engineering.info/tech/JsFrontendApp/validation-tutorial.html>]: Handling **constraint validation**.
- Part 4 [<http://web-engineering.info/tech/JsFrontendApp/unidirectional-association-tutorial.html>]: Managing **unidirectional associations**, such as the associations between books and publishers, assigning a publisher to a book, and between books and authors, assigning authors to a book.
- Part 5 [<http://web-engineering.info/tech/JsFrontendApp/bidirectional-association-tutorial.html>]: Managing **bidirectional associations**, such as the associations between books and publishers and between books and authors, not only assigning authors and a publisher to a book, but also the other way around, assigning books to authors and to publishers.
- Part 6 [<http://web-engineering.info/tech/JsFrontendApp/subtyping-tutorial.html>]: Handling **subtype** (inheritance) relationships between object types.

You may also want to take a look at our open access book Building Front-End Web Apps with Plain JavaScript [<http://web-engineering.info/JsFrontendApp-Book>], which includes all parts of the tutorial in one document, and complements them with additional material.

Chapter 1. Enumerations and Enumeration Attributes

1. Enumerations

In all application domains, there are string-valued attributes with a fixed list of possible string values. These attributes are called *enumeration attributes*, and the fixed value lists defining their possible string values are called *enumerations*. For instance, when we have to manage data about people, we often need to include information about their gender. The possible values of a `gender` attribute may be restricted to one of the **enumeration labels** "male", "female" and "undetermined", or to one of the **enumeration codes** "M", "F" and "U". Whenever we deal with codes, we also need to have their corresponding labels, at least in a legend explaining the meaning of each code.

Instead of using the enumeration string values as the internal values of an enumeration attribute, it is preferable to use a simplified internal representation for them, such as the positive integers 1, 2, 3, etc., which enumerate the possible values. However, since these integers do not reveal their meaning (which is indicated by the enumeration label) in program code, for readability we rather use special constants, called **enumeration literals**, such as `MALE` or `M`, prefixed by the name of the enumeration like in `this.gender = GenderEL.MALE`. Notice that we follow the convention that the names of enumeration literals are written all upper case, and that we also use the convention to suffix the name of an enumeration datatype with "EL" standing for "enumeration literal" (such that we can recognize from the name `GenderEL` that each instance of this datatype is a "gender enumeration literal").

There are also enumerations having records as their instances, such that one of the record fields provides the name of the enumeration literals. An example of such an enumeration is the following list of *units of measurement*:

Table 1.1. Representing an enumeration of records as a table

Units of Measurement		
Unit Symbol	Unit Name	Dimension
m	meter	length
kg	kilogram	mass
g	gram	mass
s	second	time
ms	milisecond	time

Notice that since both the "Unit Symbol" and the "Unit Name" fields are unique, either of them could be used for the name of the enumeration literals.

In summary, we can distinguish between the following three forms of enumerations:

1. **simple enumerations** define a list of self-explanatory enumeration labels;
2. **code lists** define a list of code/label pairs.
3. **record enumerations** consist of a list of records, so they are defined like classes with simple attributes defining the record fields.

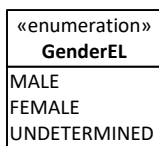
These three forms of enumerations are discussed in more detail below.

Notice that, since enumerations are used as the range of enumeration attributes, they are considered to be *datatypes*.

Enumerations may have further features. For instance, we may want to be able to define a new enumeration by extending an existing enumeration. In programming languages and in other computational languages, enumerations are implemented with different features in different ways. See also the Wikipedia article on enumerations [http://en.wikipedia.org/wiki/Enumerated_type].

1.1. Simple enumerations

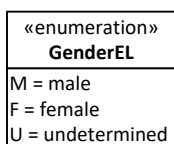
A *simple enumeration* defines a fixed list of self-explanatory enumeration labels, like in the example of a `GenderEL` enumeration shown in the following UML class diagram:



Since the labels of a simple enumeration are being used, in capitalized form, as the names of the corresponding enumeration literals (`GenderEL.MALE`, `GenderEL.FEMALE`, etc.), we may also list the (all upper case) enumeration literals in the UML enumeration datatype, instead of the corresponding (lower or mixed case) enumeration labels.

1.2. Code lists

A *code list* is an enumeration that defines a fixed list of code/label pairs. Unfortunately, the UML concept of an enumeration datatype does not support the distinction between codes as enumeration literals and their labels. For defining both codes and labels in a UML class diagram in the form of an enumeration datatype, we may use the attribute compartment of the data type rectangle and use the codes as attribute names defining the enumeration literals, and set their initial values to the corresponding label. This approach results in a visual representation as in the following diagram:



In the case of a code list, we can use both the codes or the labels as the names of enumeration literals, but using the codes seems preferable for brevity (`GenderEL.M`, `GenderEL.F`, etc.). For displaying the value of an enumeration attribute, it's an option to show not only the label, but also the code, like "male (M)", provided that there is sufficient space. If space is an issue, only the code can be shown.

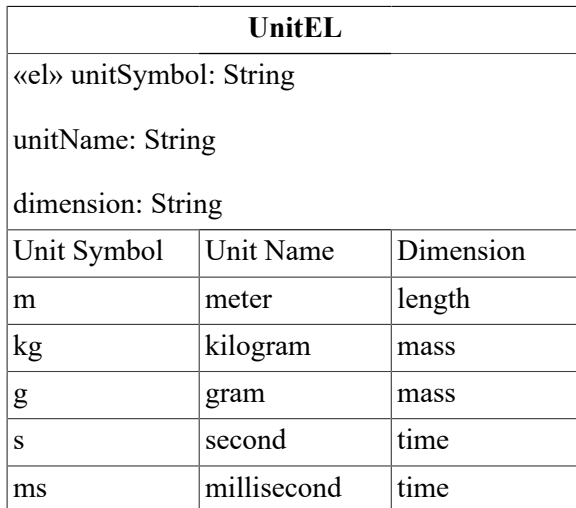
1.3. Record enumerations

A *record enumeration* defines a record type with a unique field designated to provide the enumeration literals, and a fixed list of records of that type. In general, a record type is defined by a set of field definitions (in the form of primitive datatype attributes), such that one of the unique fields is defined to be the enumeration literal field, and a set of operation definitions.

Unfortunately, record enumerations, as the most general form of an enumeration datatype, are not supported by the current version of UML (2.5) where the general form of an enumeration is defined as a special kind of datatype (with optional field and operation definitions) having an additional list of unique strings as enumeration literals (shown in a fourth compartment). The UML definition does

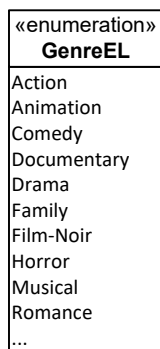
neither allow designating one of the unique fields as the enumeration literal field, nor does it allow populating an enumeration with records.

Consequently, for showing a record enumeration in a UML class diagram, we need to find a workaround. For instance, if our modeling tool allows adding a drawing, we could draw a rectangle with four compartments, such that the first three of them correspond to the name, properties and operations compartments of a datatype rectangle, and the fourth one is a table with the names of properties/fields defined in the second compartment as column headers, as shown in the following figure.



1.4. Extensible enumerations

Figure 1.1. An example of an extensible enumeration



There may be cases of enumerations that need to be extensible, that is, it must be possible to extend their list of enumeration values (labels or code/label pairs) by adding a new one. This can be expressed in a class diagram by appending an ellipsis to the list of enumeration values, as shown in Figure 1.1.

Since enumeration values are internally represented by enumeration literals, which are normally stored as plain positive integers in a database, a new enumeration value can only be added at the end of the value list such that it can be assigned a new index integer without re-assigning the indexes of other enumeration values. Otherwise, the mapping of enumeration indexes to corresponding enumeration values would not be preserved.

Alternatively, if new enumeration values have to be inserted in-between other enumeration values, and their indexes re-assigned, this implies that

1. enumeration indexes are plain sequence numbers and do no longer identify an enumeration value;

2. the value of an enumeration literal can no longer be an enumeration index, but rather has to be an identifying string: preferably the enumeration code in the case of a code list, or the enumeration label, otherwise.

2. Enumeration Attributes

An *enumeration attribute* is an attribute that has an enumeration as its range.

In the user interface, an output field for an enumeration attribute would display the enumeration label, rather than its internal value, the corresponding enumeration index.

For allowing user input to an enumeration attribute, we can use the UI concept of a (drop-down) *selection list*, which may be implemented with an HTML `select` element, such that the enumeration labels would be used as the text content of its `option` elements, while the enumeration indexes would be used as their values. We have to distinguish between *single-valued* and *multi-valued* enumeration attributes. In the case of a **single-valued** enumeration attribute, we use a standard `select` element. In the case of a **multi-valued** enumeration attribute, we use a `multi-select` element with the HTML attribute setting `multiple="multiple"`.

In the case of using a `single-select` element for an optional enumeration attribute, we need to include in its options an element like "---" for indicating that nothing has been selected. Then, the UI page for the CRUD use case "Create" shows "---" as the initially selected option.

For both cases, an example is shown in Figure 1.2. While the single `select` element for "Original language" shows the initially selected option "---" denoting "nothing selected", the multiple `select` element "Other available languages" shows a small window displaying four of the options that can be selected.

For usability, the multiple selection list can only be implemented with an HTML `select` element, if the number of enumeration literals does not exceed a certain threshold (like 20), which depends on the number of options the user can see on the screen without scrolling.

For user input for a **single-valued** enumeration attribute, a **radio button group** can be used instead of a single selection list, if the number of enumeration literals is sufficiently small (say, not larger than 7). A radio button group is implemented with an HTML `fieldset` element acting as a container of labeled `input` elements of type "radio", all having the same name, which is normally equal to the name of the represented enumeration attribute.

For user input for a **multi-valued** enumeration attribute, a **checkbox group** can be used instead of a multiple selection list, if the number of enumeration literals is sufficiently small (say, not larger than 7). A checkbox group is implemented with an HTML `fieldset` element acting as a container of labeled `input` elements of type "checkbox", all having the same name, which is normally equal to the name of the represented enumeration attribute.

3. Enumerations in Computational Languages

Defining enumerations is directly supported in information modeling languages (such as in *UML Class Diagrams*), in data schema languages (such as in *XML Schema*, but not in *SQL*), and in many programming languages (such as in *C++* and *Java*, but not in *JavaScript*).

3.1. Enumerations in SQL

Unfortunately, standard SQL does not support enumerations. Some DBMS, such as *MySQL* and *Postgres*, provide their own extensions of SQL column definitions in the CREATE TABLE statement allowing to define enumeration-valued columns.

A MySQL enumeration [<https://dev.mysql.com/doc/refman/5.7/en/enum.html>] is specified as a list of enumeration labels with the keyword ENUM within a column definition, like so:

```
CREATE TABLE people (  
    name VARCHAR(40),  
    gender ENUM('MALE', 'FEMALE', 'UNDETERMINED')  
);
```

A Postgres enumeration [<http://postgresguide.com/sexy/enums.html>] is specified as a special user-defined type that can be used in column definitions:

```
CREATE TYPE GenderEL AS ENUM ('MALE', 'FEMALE', 'UNDETERMINED');  
CREATE TABLE people (  
    name text,  
    gender GenderEL  
)
```

3.2. Enumerations in XML Schema

In XML Schema, an enumeration datatype can be defined as a simple type restricting the primitive type `xs:string` in the following way:

```
<xs:simpleType name="BookCategoryEL">  
  <xs:restriction base="xs:string">  
    <xs:enumeration value="NOVEL"/>  
    <xs:enumeration value="BIOGRAPHY"/>  
    <xs:enumeration value="TEXTBOOK"/>  
    <xs:enumeration value="OTHER"/>  
  </xs:restriction>  
</xs:simpleType>
```

3.3. Enumerations in JavaScript

In JavaScript, we can define an enumeration as a special JS object having a property for each enumeration literal such that the property's name is the enumeration literal's name (the enumeration label or code in upper case) and its value is the corresponding enumeration index. One approach for implementing this is using the `Object.defineProperties` method:

```
var BookCategoryEL = null;  
Object.defineProperties( BookCategoryEL, {  
  NOVEL: {value: 1, writable: false},  
  BIOGRAPHY: {value: 2, writable: false},  
  TEXTBOOK: {value: 3, writable: false},  
  OTHER: {value: 4, writable: false},  
  MAX: {value: 4, writable: false},  
  labels: {value:["novel","biography","textbook","other"],
```

```
writable: false}
});
```

This definition allows using the enumeration literals `BookCategoryEL.NOVEL`, `BookCategoryEL.BIOGRAPHY` etc., standing for the enumeration indexes 1, 2, 3 and 4, in program statements. Notice how this definition takes care of the requirement that enumeration literals like `BookCategoryEL.NOVEL` are constants, the value of which cannot be changed during program execution. This is achieved with the help of the property descriptor `writable: false` in the `Object.defineProperty` statement.

We can also use a more generic approach and define a meta-class `Enumeration` for creating enumerations in the form of special JS objects:

```
function Enumeration( enumLabels) {
  var i=0, LBL="";
  this.MAX = enumLabels.length;
  this.labels = enumLabels;
  // generate the enum literals as capitalized keys/properties
  for (i=1; i <= enumLabels.length; i++) {
    LBL = enumLabels[i-1].toUpperCase();
    this[LBL] = i;
  }
  // prevent any runtime change to the enumeration
  Object.freeze( this);
};
```

Using this `Enumeration` class allows to define a new enumeration in the following way:

```
var BookCategoryEL = new Enumeration(["novel", "biography", "textbook", "other"])
```

Having an enumeration like `BookCategoryEL`, we can then check if an enumeration attribute like `category` has an admissible value by testing if its value is not smaller than 1 and not greater than `BookCategoryEL.MAX`. Also, the label can be retrieved in the following way:

```
formEl.category.value = BookCategoryEL.labels[this.category - 1];
```

As an example, we consider the following model class `Book` with the enumeration attribute `category`:

```
function Book( slots) {
  this.isbn = ""; // string
  this.title = ""; // string
  this.category = 0; // number (BookCategoryEL)
  if (arguments.length > 0) {
    this.setIsbn( slots.isbn);
    this.setTitle( slots.title);
    this.setCategory( slots.category);
  }
};
```

For validating input values for the enumeration attribute `category`, we can use the following check function:

```
Book.checkCategory = function (c) {
  if (!c) {
    return new MandatoryValueConstraintViolation(
```

```

    "A category must be provided!");
} else if (!Number.isInteger(c) || c < 1 ||
           c > BookCategoryEL.MAX) {
    return new RangeConstraintViolation(
        "The category must be a positive integer " +
        "not greater than "+ BookCategoryEL.MAX + " !");
} else {
    return new NoConstraintViolation();
}
};

```

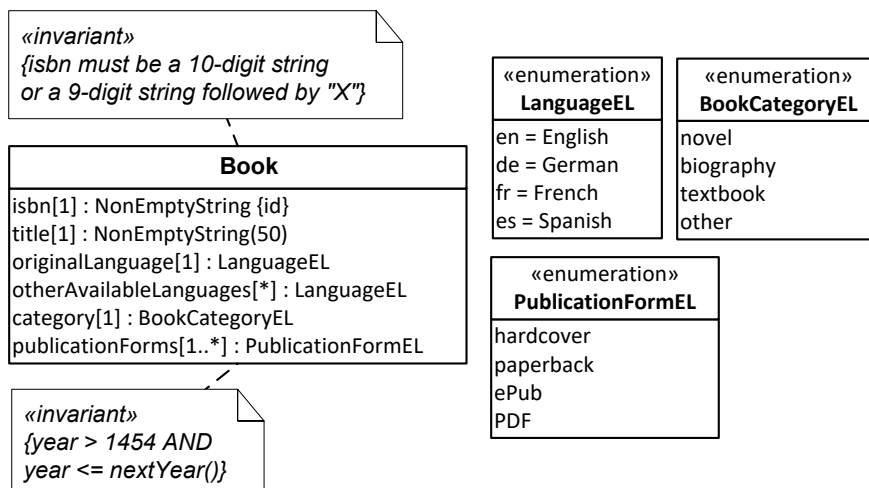
Notice how the range constraint defined by the enumeration `BookCategoryEL` is checked: it is tested if the input value `c` is a positive integer and if it is not greater than `BookCategoryEL.MAX`.

4. Dealing with Enumeration Attributes in a Design Model

We again consider the simple data management problem that we have considered before. So, again, the purpose of our app is to manage information about books. But now we have four additional *enumeration attributes*, as shown in the UML class diagram in Figure 1.5 below:

1. the single-valued mandatory attribute `originalLanguage` with the enumeration datatype `LanguageEL` as its range,
2. the multi-valued optional attribute `otherAvailableLanguages` with range `LanguageEL`,
3. the single-valued mandatory attribute `category` with range `BookCategoryEL`
4. the multi-valued mandatory attribute `publicationForms` with range `PublicationFormEL`

Figure 1.5. An information design model for the object type `Book`



Notice that the attributes `otherAvailableLanguages` and `publicationForms` are *multivalued*, as indicated by their multiplicity expressions `[*]` and `[1..*]`. This means that the possible values of these attributes are sets of enumeration literals, such as the set `{ePub, PDF}`, which can be represented in JavaScript as a corresponding array list of enumeration literals, `[PublicationFormEL.EPUB, PublicationFormEL.PDF]`.

The meaning of the design model and its enumeration attributes can be illustrated by a sample data population:

Table 1.2. Sample data for Book

ISBN	Title	Original language	Other languages	Category	Publication forms
0553345842	The Mind's I	English (en)	de, es, fr	novel	paperback, ePub, PDF
1463794762	The Critique of Pure Reason	German (de)	de, es, fr, pt, ru	other	paperback, PDF
1928565379	The Critique of Practical Reason	German (de)	de, es, fr, pt, ru	other	paperback
0465030793	I Am A Strange Loop	English (en)	es	textbook	hardcover, ePub

Chapter 2. Implementing Enumeration Attributes in a Plain JS Web App

In this chapter, we show how to build a front-end web application with **enumeration attributes**, using plain JavaScript. We also show how to deal with *multi-valued attributes* because in many cases, enumeration attributes are multi-valued.

1. New Issues

Compared to the Validation App [<http://web-engineering.info/tech/JsFrontendApp/ValidationApp/index.html>] discussed in Part 2 (Validation App Tutorial [<http://web-engineering.info/tech/JsFrontendApp/validation-tutorial.html>]), we now deal with the following new issues:

1. We replace the ES5 constructor-function-based class definition of our model class `Book` with a corresponding ES6 `class` definition, which provides a more convenient syntax while preserving the prototype-based semantics of JS constructor functions.
2. Instead of defining explicit setters we now make use of implicit `get/set` methods for properties because they can be conveniently defined within a `class` definition.
3. *Enumeration datatypes* have to be defined in a suitable way as part of the model code.
4. *Enumeration attributes* have to be defined in model classes and handled in the user interface with the help of suitable *choice widgets*.

In terms of coding, the new issues are:

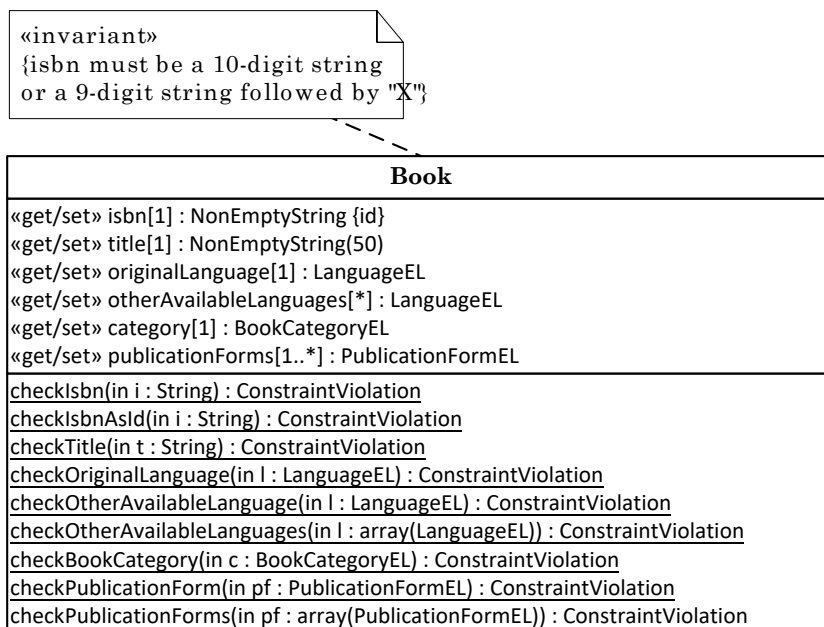
1. In the *model* code we now have to take care of
 - a. defining an ES6 `class` for `Book`;
 - b. defining `get/set` methods for all properties of the `Book` class definition;
 - c. defining the **enumerations** with the help of a utility class `Enumeration`, which is discussed below;
 - d. defining the **single-valued enumeration attributes** `originalLanguage` and `category` together with their check functions `checkOriginalLanguage` and `checkCategory`;
 - e. defining the **multi-valued enumeration attributes** `otherAvailableLanguages` and `publicationForms` together with their check functions `checkOtherAvailableLanguages` and `checkPublicationForms`;
 - f. extending the methods `Book.update` and `Book.prototype.toString` such that they take care of the added enumeration attributes;
 - g. defining a `Book.prototype.toJSON` function for facilitating the conversion from a `Book` object to a corresponding JSON record;
 - h. defining extensions of the built-in JS object `Array`, representing a class, by adding two class-level functions (`max` and `min`), and two instance-level functions (`clone` and `isEqualTo`) in `browserShims.js`.

2. In the *user interface* ("view") code we have to take care of
 - a. adding new table columns in `retrieveAndListAllBooks.html` and suitable choice widgets in `createBook.html` and `updateBook.html`;
 - b. creating output for the new attributes in `v/retrieveAndListAllBooks.mjs`;
 - c. allowing input for the new attributes in `v/createBook.mjs` and `v/updateBook.mjs`.

2. Make a JavaScript Class Model

Using the information design model shown in Figure 1.5 above as the starting point, we make a *JavaScript* class model, essentially by decorating properties with a «get/set» stereotype, implying that they have implicit getters and setters, and by adding (class-level) check methods:

Figure 2.1. A JS class model for the object type Book



Notice that, for any multi-valued enumeration attribute (like `someThings`) we add a class-level check function for single values (like `checkSomeThing`) and another one for value sets (like `checkSomeThings`), both returning an object of type `ConstraintViolation`.

The implicit getters and setters implied by the «get/set» stereotype are a special feature of ES5, allowing to define methods for getting and setting the value of a property *p* while keeping the simple syntax of getting its value with `v = o.p`, and setting it with `o.p = expr`. They require to define another, internal, property (like `_p`) for storing the value of *p* because the name "p" does not refer to a normal property, but rather to a pair of get/set methods.

The most common reason for using implicit getters and setters is the need to always check constraints before setting a property. This is also the reason why we use them.

3. Add Two Library Files

The folder structure of our enumeration app extends the structure of the validation app by adding the library files `browserShims.js` and `Enumeration.mjs` in the `lib` folder. Thus, we get the following folder structure with four files in the `lib` folder:

```
publicLibrary
  css
  lib
    browserShims.js
    errorTypes.mjs
    util.mjs
    Enumeration.mjs
  src
  index.html
```

In the `browserShims.js` file, we define a few extensions of the built-in JS object `Array`, representing a class, by adding two class-level functions (`max` and `min`), and two instance-level functions (`clone` and `isEqualTo`). These helper functions are used, e.g., in `v/updateBook.mjs`.

In the `Enumeration.js` file, discussed in the next section, we define a meta-class `Enumeration` for creating enumerations as instances of this meta-class with the help of statements like `GenderEL = new Enumeration(["male", "female", "other"])`.

4. The Meta-Class Enumeration

We define an `Enumeration` meta-class, which supports both simple enumerations and code lists (but not record enumerations). While a simple enumeration is defined by a list of labels in the form of a JS array as the constructor argument such that the labels are used for the names of the enumeration literals, a code list is defined as a special kind of key-value map in the form of a JS object as the constructor argument such that the codes are used for the names of the enumeration literals. Consequently, the constructor needs to test if the invocation argument is a JS array or not. The following first part of the code shows how simple enumerations are created:

```
function Enumeration( enumArg) {
  if (Array.isArray( enumArg)) {
    // a simple enumeration defined by a list of labels
    if (!enumArg.every( function (l) {
      return (typeof l === "string"); })) {
      throw new ConstraintViolation(
        "A list of enumeration labels must be an array of strings!");
    }
    this.labels = enumArg;
    this.enumLitNames = this.labels;
    this.codeList = null;
  } else if (...) {
    ... // a code list defined by a code/label map
  }
  this.MAX = this.enumLitNames.length;
  // generate the enumeration literals by capitalizing/normalizing
  for (let i=1; i <= this.enumLitNames.length; i++) {
    // replace " " and "-" with "_"
  }
}
```

```
const lbl = this.enumLitNames[i-1].replace(/( |-)/g, "_");
// convert to array of words, capitalize them, and re-convert
const LBL = lbl.split("_").map( lblPart => lblPart.toUpperCase()).join("_")
// assign enumeration index
this[LBL] = i;
}
Object.freeze( this);
};
```

After setting the `MAX` property of the newly created enumeration, the enumeration literals are created in a loop as further properties of the newly created enumeration such that the property name is the normalized label string and the value is the index, or sequence number, starting with 1. Notice that a label string like "text book" or "text-book" is normalized to the enumeration literal name "TEXT_BOOK", following a widely used convention for constant names. Finally, by invoking `Object.freeze` on the newly created enumeration, all its properties become 'unwritable' (or read-only).

The following second part of the code shows how code list enumerations are created:

```
function Enumeration( enumArg) {
  if (Array.isArray( enumArg)) { // a simple enumeration
    ...
  } else if (typeof enumArg === "object" &&
    Object.keys( enumArg).length > 0) {
    // a code list defined by a code/label map
    if (!Object.keys( enumArg).every( function (code) {
      return (typeof enumArg[code] === "string"); })) {
      throw new OtherConstraintViolation(
        "All values of a code/label map must be strings!");
    }
    this.codeList = enumArg;
    // use the codes as the names of enumeration literals
    this.enumLitNames = Object.keys( this.codeList);
    this.labels = this.enumLitNames.map(
      c => `${enumArg[c]} (${c})`);
  }
  ...
};
```

Notice that the code list labels in `this.labels` are extended by appending their codes in parenthesis.

5. Write the Model Code

5.1. Code the enumerations

Three enumerations are coded (within `Book.mjs`) in the following way with the help of the meta-class `Enumeration`:

```
const PublicationFormEL = new Enumeration(
  ["hardcover", "paperback", "ePub", "PDF"]);
const BookCategoryEL = new Enumeration(
  ["novel", "biography", "textbook", "other"]);
const LanguageEL = new Enumeration({ "en": "English",
  "de": "German", "fr": "French", "es": "Spanish" });
```

Notice that LanguageEL defines a code list enumeration, while PublicationFormEL and BookCategoryEL define simple enumerations.

5.2. Code the model class as a JS class

We want to check if a new property value satisfies all constraints of a property whenever the value of a property is set. A best practice approach for making sure that new values are validated before assigned is using a setter method for assigning a property, and invoking the check in the setter. We can either define an explicit setter method (like `setIsbn`) for a property (like `isbn`), or we can use JavaScript's implicit getters and setters in combination with an internal property name (like `__isbn`). We have used explicit setters in the validation app. Now, in the `Book` class definition for the enumeration app, we use JavaScript's implicit getters and setters because they offer a more user-friendly syntax and can be conveniently defined in an ES6 (or ES2015) class definition.

The properties of the class `Book` are defined with an internal property name format (prefixed with `__`) and assigned with values from corresponding key-value slots of a `slots` parameter in the constructor:

```
class Book {
  constructor (slots) {
    // assign default values to mandatory properties
    this.__isbn = ""; // string
    this.__title = ""; // string
    ...
    // is constructor invoked with a non-empty slots argument?
    if (typeof slots === "object" && Object.keys( slots).length > 0) {
      // assign properties by invoking implicit setters
      this.isbn = slots.isbn;
      this.title = slots.title;
      ...
    }
  }
  ...
}
```

5.3. Code the implicit getters and setters

For each property, we define implicit getters and setters using the predefined JS keywords `get` and `set`:

```
class Book {
  ...
  get isbn() {
    return this.__isbn;
  }
  set isbn( n) {
    var validationResult = Book.checkIsbnAsId( n);
    if (validationResult instanceof NoConstraintViolation) {
      this.__isbn = n;
    } else {
      throw validationResult;
    }
  }
  ...
}
```

Notice that the implicit getters and setters access the corresponding internal property, like `_isbn`. This approach is based on the assumption that this internal property is normally not accessed directly, but only via its getter or setter. Since we can normally assume that developers comply with this rule (and that there is no malicious developer in the team), this approach is normally safe enough. However, there is also a proposal to increase the safety (for avoiding direct access) by generating random names for the internal properties with the help of the ES2015 `Symbol` class.

5.4. Code the enumeration attribute checks

Code the enumeration attribute checks in the form of class-level ('static') functions that check if the argument is a valid enumeration index not smaller than 1 and not greater than the enumeration's `MAX` value. For instance, for the `checkOriginalLanguage` function we obtain the following code:

```
class Book {
  ...
  static checkOriginalLanguage( ol ) {
    if ( ol === undefined || ol === "" ) {
      return new MandatoryValueConstraintViolation(
        "An original language must be provided!");
    } else if ( !isIntegerOrIntegerString( ol ) ||
      parseInt(ol) < 1 || parseInt(ol) > LanguageEL.MAX ) {
      return new RangeConstraintViolation(
        `Invalid value for original language: ${ol}`);
    } else {
      return new NoConstraintViolation();
    }
  }
  ...
}
```

For a multi-valued enumeration attribute, such as `publicationForms`, we break down the validation code into two check functions, one for checking if a value is a valid enumeration index (`checkPublicationForm`), and another one for checking if all members of a set of values are valid enumeration indexes (`checkPublicationForms`). The first check is coded as follows:

```
static checkPublicationForm( p ) {
  if ( p == undefined ) {
    return new MandatoryValueConstraintViolation(
      "No publication form provided!");
  } else if ( !Number.isInteger( p ) || p < 1 ||
    p > PublicationFormEL.MAX ) {
    return new RangeConstraintViolation(
      `Invalid value for publication form: ${p}`);
  } else {
    return new NoConstraintViolation();
  }
}
```

The second check first tests if the argument is a non-empty array (representing a collection with at least one element) and then checks all elements of the array in a loop:

```
static checkPublicationForms( pubForms ) {
  if ( !pubForms || (Array.isArray( pubForms ) &&
    pubForms.length === 0) ) {
```

```
    return new MandatoryValueConstraintViolation(
      "No publication form provided!");
  } else if (!Array.isArray( pubForms)) {
    return new RangeConstraintViolation(
      "The value of publicationForms must be an array!");
  } else {
    for (let i of pubForms.keys()) {
      const validationResult = Book.checkPublicationForm( pubForms[i]);
      if (!(validationResult instanceof NoConstraintViolation)) {
        return validationResult;
      }
    }
  }
  return new NoConstraintViolation();
}
```

5.5. Write a serialization function

The object serialization function `toString()` now needs to include the values of enumeration attributes:

```
class Book {
  ...
  toString() {
    return `Book{ ISBN: ${this.isbn}, title: ${this.title},
      originalLanguage: ${this.originalLanguage},
      otherAvailableLanguages: ${this.otherAvailableLanguages.toString()},
      category: ${this.category},
      publicationForms: ${this.publicationForms.toString()} `;
  }
}
```

Notice that for the multi-valued enumeration attributes we call the `toString()` function that is predefined for JS arrays.

5.6. Data management operations

There are only two new issues in the data management operations compared to the validation app:

1. We have to make sure that the `cloneObject` method, which is used in `Book.update`, takes care of copying array-valued attributes, which we didn't have before (in the validation app).
2. In the `Book.update` method we now have to check if the values of array-valued attributes have changed, which requires to test if two arrays are equal or not. For code readability, we add an array equality test method to `Array.prototype` in `browserShims.js`, like so:

```
Array.prototype.isEqualTo = function (a2) {
  return (this.length === a2.length) && this.every( function( el, i) {
    return el === a2[i]; });
};
```

This allows us to express these tests in the following way:

```
if (!book.publicationForms.isEqualTo( slots.publicationForms)) {
  book.publicationForms = slots.publicationForms;
}
```

```
    updatedProperties.push("publicationForms");  
  }
```

5.7. Creating test data

In the test data records that are created by `Book.createTestData()`, we now have to provide values for single- and multi-valued enumeration attributes. For readability, we use enumeration literals instead of enumeration indexes:

```
Book.generateTestData = function () {  
  try {  
    Book.instances["006251587X"] = new Book({isbn:"006251587X",  
      title:"Weaving the Web", originalLanguage: LanguageEL.EN,  
      otherAvailableLanguages: [LanguageEL.DE, LanguageEL.FR],  
      category: BookCategoryEL.NOVEL,  
      publicationForms: [PublicationFormEL.EPUB,  
        PublicationFormEL.PDF]  
    });  
    ...  
    Book.saveAll();  
  } catch (e) {  
    console.log(`${e.constructor.name}: ${e.message}`);  
  }  
};
```

6. Write the View Code

The example app's user interface (UI) for creating a new book record looks as in Figure 2.2 below.

Figure 2.2. The UI for creating a new book record with enumeration attributes

The screenshot shows a web form for creating a new book record. It contains the following elements:

- ISBN: A text input field.
- Title: A text input field.
- Original language: A dropdown menu with a downward arrow.
- Other available languages: A list box with upward and downward arrows, containing the following options: English (en), German (de), French (fr), and Spanish (es).
- Category: A horizontal line with four radio buttons labeled "novel", "biography", "textbook", and "other".
- Publication forms: A horizontal line with four checkboxes labeled "hardcover", "paperback", "ePub", and "PDF".
- Save: A button labeled "Save".
- Back to main menu: A link labeled "Back to main menu".

Notice that the UI contains four choice widgets:

1. a *single selection list* for the attribute `originalLanguage`,

2. a *multiple selection list* for the attribute `otherAvailableLanguages`,
3. a *radio button group* for the attribute `category`, and
4. a *checkbox group* for the attribute `publicationForms`.

6.1. Selection lists

We use HTML selection lists for rendering the enumeration attributes `originalLanguage` and `otherAvailableLanguages` in the HTML forms in `createBook.html` and `updateBook.html`. Since the attribute `otherAvailableLanguages` is multi-valued, we need a **multiple** selection list for it, as shown in the following HTML code:

```
<form id="Book">
  <div><label>ISBN:
    <input name="isbn" type="text" /></label></div>
  <div><label>Title:
    <input name="title" type="text" /></label></div>
  <div><label>Original language:
    <select name="originalLanguage"></select>
  </label></div>
  <div class="multi-sel"><label>Also available in:
    <select name="otherAvailableLanguages"
      multiple="multiple" rows="4"></select>
  </label></div>
  ...
  <div><button type="submit" name="commit">Save
    </button></div>
</form>
```

While we define the `select` container elements for these selection lists in the HTML code of `createBook.html` and `updateBook.html`, we fill in their `option` child elements dynamically in the `setupUserInterface` methods in `v/createBook.mjs` and `v/updateBook.mjs` with the help of the utility method `fillSelectWithOptions`.

In the case of a single `select` element, the user's single-valued selection can be retrieved from the `value` attribute of the `select` element, while in the case of a multiple `select` element, the user's multi-valued selection can be retrieved from the `selectedOptions` attribute of the `select` element.

Notice that the `div` element containing the multiple selection list for `otherAvailableLanguages` has the `class` value `"multi-sel"`, which is used for defining specific CSS rules that adjust the element's size.

6.2. Radio button and checkbox groups

Since the enumeration attributes `category` and `publicationForms` do not have more than seven possible values, we can use a *radio button group* and a *checkbox group* for rendering them in an HTML-form-based UI. These choice widgets are formed with the help of the container element `fieldset` and its child element `legend` as shown in the following HTML fragment:

```
<form id="Book">
  ...
  <fieldset data-bind="category">
```

```
<legend>Category</legend></fieldset>
<fieldset data-bind="publicationForms">
  <legend>Publication forms</legend></fieldset>
<div><button type="submit" name="commit">Save
  </button></div>
</form>
```

Notice that we use a custom attribute `data-bind` for indicating to which attribute of the underlying model class the choice widget is bound.

In the same way as the `option` child elements of a selection list, also the labeled input child elements of a choice widget are created dynamically with the help of the utility method `createChoiceWidget` in `v/createBook.js` and `v/updateBook.js`.

```
const formEl = document.forms["Book"],
    origLangSelEl = formEl["originalLanguage"],
    otherAvailLangSelEl = formEl["otherAvailableLanguages"],
    categoryFieldsetEl = formEl.querySelector(
      "fieldset[data-bind='category']"),
    pubFormsFieldsetEl = formEl.querySelector(
      "fieldset[data-bind='publicationForms']"),
    saveButton = formEl["commit"];
// load all book records
Book.retrieveAll();
// set up the originalLanguage selection list
fillSelectWithOptions( origLangSelEl, LanguageEL.labels);
// set up the otherAvailableLanguages selection list
fillSelectWithOptions( otherAvailLangSelEl, LanguageEL.labels);
// set up the category radio button group
createChoiceWidget( categoryFieldsetEl, "category", [],
  "radio", BookCategoryEL.labels, true);
// set up the publicationForms checkbox group
createChoiceWidget( pubFormsFieldsetEl, "publicationForms", [],
  "checkbox", PublicationFormEL.labels);
```

Notice that like a selection list implemented with the HTML `select` element that provides the user's selection in the `value` or `selectedOptions` attribute, our choice widgets also need a DOM attribute that holds the user's single- or multi-valued choice. We dynamically add a custom attribute `data-value` to the choice widget's `fieldset` element for this purpose in `createChoiceWidget`.

6.3. Responsive validation for choice widgets

Since choice widgets do not allow arbitrary user input, we do not have to check constraints such as range constraints or pattern constraints on user input, but only mandatory value constraints. This allows simplifying responsive validation in the UI.

In our example app, the enumeration attributes `originalLanguage`, `category` and `publicationForms` are mandatory, while `otherAvailableLanguages` is optional.

In the case of a *mandatory single-valued* enumeration attribute like `originalLanguage` rendered as a single selection list, we can enforce a choice, and thus the mandatory value constraint, by not offering an empty or void option among the `option` sub-elements of the `select` element. If the attribute is rendered as a radio button group, we can enforce a choice, and thus the mandatory value constraint, in the *create* use case by initially setting the `checked` attribute of the first radio button to `true` and not

allowing the user to directly uncheck a button. In this way, if the user doesn't check any button, the first one is the default choice.

In the case of an *optional single-valued* enumeration attribute rendered as a single-selection list, we need to include an empty or void option (e.g., in the form of a string like "---"). If the attribute is rendered as a radio button group, we do not check any button initially and we need to allow the user to directly uncheck a button with a mouse click in a `click` event listener.

In the case of a *mandatory multi-valued* enumeration attribute like `publicationForms` rendered as a multiple-selection list or checkbox group, we need to check if the user has chosen at least one option. Whenever the user selects or unselects an option in a `select` element, a `change` event is raised by the browser, so we can implement the responsive mandatory value constraint validation as an event listener for `change` events on the `select` element, by testing if the list of `selectedOptions` is empty. If the attribute is rendered as a checkbox group, we need an event listener for `click` events added on the `fieldset` element and testing if the widget's value set is non-empty, as shown in the following example code fragment:

```
pubFormsFieldsetEl.addEventListener("click", function () {
  const val = pubFormsFieldsetEl.getAttribute("data-value");
  formEl.publicationForms[0].setCustomValidity(
    (!val || Array.isArray(val) && val.length === 0) ?
      "At least one publication form must be selected!":"" );
});
```

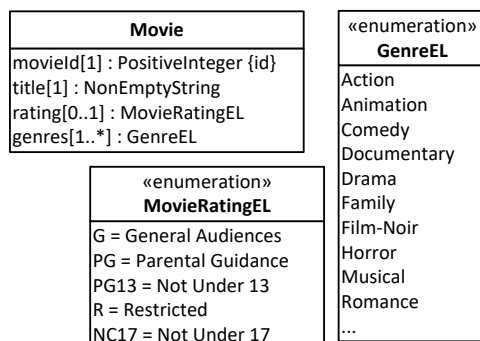
Notice that the HTML5 constraint validation API does not allow to indicate a constraint violation on a `fieldset` element (as the container element of a choice widget). As a workaround, we use the first checkbox element of the `publicationForms` choice widget, which can be accessed with `formEl.publicationForms[0]`, for invoking the `setCustomValidity` method that indicates a constraint violation if its argument is a non-empty (message) string.

You can run the enumeration app [<http://web-engineering.info/tech/JsFrontendApp/EnumerationApp/index.html>] from our server or download the code [<http://web-engineering.info/tech/JsFrontendApp/EnumerationApp.zip>] as a ZIP archive file.

7. Practice Project

The purpose of the app to be built is managing information about movies. The app deals with just one object type, `Movie`, and with two enumerations, as depicted in the following class diagram. In the subsequent parts of the tutorial, you will extend this simple app by adding actors and directors as further model classes, and the associations between them.

Figure 2.3. The object type `Movie` defined together with two enumerations.



First make a list of all the constraints that have been expressed in this model. Then code the app by following the guidance of this tutorial and the Validation Tutorial [<http://web-engineering.info/tech/JsFrontendApp/validation-tutorial.html>].

Compared to the practice project of our validation tutorial, two attributes have been added: the optional single-valued enumeration attribute `rating`, and the multi-valued enumeration attribute `genres`.

Following the tutorial, you have to take care of

1. defining the *enumeration data types* `MovieRatingEL` and `GenreEL` with the help of the meta-class `Enumeration`;
2. defining the *single-valued enumeration attribute* `Movie::rating` together with a check and a setter;
3. defining the *multi-valued enumeration attributes* `Movie::genres` together with a check and a setter;
4. extending the methods `Movie.update`, and `Movie.prototype.toString` such that they take care of the added enumeration attributes.

in the *model* code of your app, while In the *user interface* ("view") code you have to take care of

1. adding new table columns in `retrieveAndListAllMovies.html` and suitable form controls (such as *selection lists*, *radio button groups* or *checkbox groups*) in `createMovie.html` and `updateMovie.html`;
2. creating output for the new attributes in `v/retrieveAndListAllMovies.mjs`;
3. allowing input for the new attributes in `v/createMovie.mjs` and `v/updateMovie.mjs`.

You can use the following sample data for testing your app:

Table 2.1. Sample data

Movie ID	Title	Rating	Genres
1	Pulp Fiction	R	Crime, Drama
2	Star Wars	PG	Action, Adventure, Fantasy, Sci-Fi
3	Casablanca	PG	Drama, Film-Noir, Romance, War
4	The Godfather	R	Crime, Drama

In this assignment, and in all further assignments, you have to make sure that your pages comply with the XML syntax of HTML5 (by means of XHTML5 validation), and that your JavaScript code complies with our Coding Guidelines [<http://oxygen.informatik.tu-cottbus.de/webeng/Coding-Guidelines.html>] and is checked with JSHint (<http://www.jshint.com> [<http://www.jshint.com/>]).