



**Hochschule für Technik  
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# **Automatic Interaction Diagram Generation of Vue.js-based Web Applications**

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## **Abstract**

In this thesis an implementation of an n=gram based language model using the Modified Kneser=Ney smoothing algorithm with the open source Apache Spark large scale data processing engine and the open source document oriented database MongoDB will be presented. This language model will then be used to generate sentences from input sets of keywords.

This thesis aims to further explore the concept of interaction diagrams for scenario testing introduced by [ZZ19]. It is applied to a different framework (Vue.js) ... how scenarios in Gherkin generated and extended lists.

—

automatically generate!!!

—

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## Chapter 1

# Introduction

## Chapter 2

# Fundamentals and State of The Art

### 2.1 State of the Art

TODO

#### 2.1.1 TODO some papers

### 2.2 Scenario Testing of AngularJS-based Single Page Web Applications

Zhang and Zhao [ZZ19] present a method with the goal of achieving better understanding of AngularJS-based single page applications (SPAs) and also devised a way to specify test coverage criteria based on it. At the center of the proposed method are interaction diagrams, which are used to model the overall data and control flow of an application.[ZZ19]

#### 2.2.1 Abstract Syntax

Zhang and Zhao [ZZ19] model a AngularJS-based SPA as a tuple  $(T, C, D, E)$ , where

- $T$  is a HTML template, consisting of a set of HTML tags (widgets) ( $T = \{h\}$ )
- $C$  is a controller (view-model), written in JavaScript. It is modeled as a tuple  $(V, F, \$scope)$ , where  $F$  and  $V$  are top level variables and functions respectively and  $\$scope \in V$  is a distinguished element of  $V$ . Further  $V(\$scope)$  and  $F(\$scope)$  denote all variables and functions of  $\$scope$  respectively.  $W = V \setminus \{\$scope\}$  denotes top level variables not in scope. Additionally  $init \in F$  is defined as an initialization function
- $D$  is a set of data bindings between HTML tags and variable properties of  $\$scope$   $D \subseteq \{(h, V(\$scope) \cup F(\$scope))\}$ . Given  $d = (n, o)$   $source(d) = n$  and  $target(d) = o$ . For Two-way bindings  $D' \subseteq D$  and  $\forall d \in D'$   $target(d) \in V(\$scope)$ .

- $E$  a set of event handler bindings between HTML tags and function properties of  $\$scope$ :  $E \subset \{(h, F(\$scope))\}$ . In addition, for each function  $f \in F \cup F(\$scope)$ ,  $R(f) \subseteq V \cup V(\$scope)$  and  $W(f) \subseteq V \cup V(\$scope)$  are defined as the values that the given function reads from and writes to.  $Inv(f) \in F$  are defined as the functions invoked by  $f$ . [ZZ19]

### 2.2.2 Interaction Diagrams

Zhang and Zhao [ZZ19] define interaction diagrams as a directed graph  $(N, E)$  where the set of nodes  $N$  is defined as the union of  $N_H$  (HTML tag nodes),  $N_{\$scope}$  (TODO name),  $N_js$  (TODO name).  $N_H = \{n_h | (h, v) \in D\}$

$$N_{\$scope} = \{n_v | (h, v) \in D\} \cup \{n_e | (h, e) \in E\}$$

$$N_js = \{n_v | v \in W\} \cup \{n_f | f \in F\}$$

$n_{init}$  is distinguished by an incoming arrow without a starting vertex

Edges:

bindings

$$e_d = (target(d), source(d)) \quad E_{data} = \{e_d | d \in D\}$$

additionally if  $d \in D'$  also create  $e'_t = (source(t), target(t))$  and  $E'_{data} = \{e_d | d \in D'\}$

for events ( $E_{event}$ )  $(h, f) \in E$ ,

write  $E_W (f, v)$  where  $f \in F \cup F(\$scope), v \in W(f)$

read  $E_R (v, f)$  where  $f \in F \cup F(\$scope), v \in R(f)$

invoked  $E_{Inv} (f, v)$  where  $f \in F \cup F(\$scope), v \in I(f)$

$E_{init}$  default values of widgets for each  $h \in T$  where  $\nexists v | (h, v) \in D$  create an edge  $(h, v)$  explained in a lot of detail in [ZZ19, p. 9]

### 2.2.3 Testing and Interactions

Zhang and Zhao [ZZ19] define an interaction as a round of user input including updates to the widgets by the application. Interaction can be triggered explicitly by the user (by invoking an event handler) or implicitly while the user is updating data. [ZZ19]

Given the interaction diagrams as described in 2.2.2 it is possible to derive which widgets get updated by a user input action or set up by the initial function. Zhang and Zhao [ZZ19] define it formally as follows:

Given a node  $n \in N_H \cup \{init\}$ , we say a node  $m \in N_H$  reacts to  $n$  iff

1.  $\exists n_0, n_1, n_2, \dots, n_k \in N, n_0 = n, n_k = m$  such that for each  $0 \leq i < k$   $(n_i, n_{i+1}) \in E$ , and
2.  $\forall n_p, 1 < p \leq k$  and  $\forall e \in E, target(e) = n_p$  it holds that  $e \notin E_{event}$

We write  $l(n)$  for the set of all nodes representing the widgets that react to  $n$ . This set contains the widgets that are automatically updated upon user input, and thus constitute an interaction.

For example, in order for the widget  $n$ , which was clicked by the user, to update the widget  $m$ ,  $m$  must be reachable from  $n$  by following the directed edges of the interaction diagram and only the first edge can be an event-handling edge.

What is crucial is that the interactions  $l(n)$  define an upper bound of what can be updated, i.e. what might get updated. Nevertheless, this information is sufficient in order to be able to define coverage criteria [ZZ19].

## 2.2.4 Coverage Criteria

Interactions should not be tested in isolation and in order for tests to make sense, interactions as preconditions are required [ZZ19]. In order to define coverage criteria, Zhang and Zhao [ZZ19] extend their notation, as described in 2.2.2, by defining  $\mathcal{I} = \{w \in T \mid l(w) \neq \emptyset\}$  all widgets, that result updates.

A sequence of user interactions, including the initial function is referred to as a *scenario*  $A = (a_0, a_1, \dots, a_n)$  where  $a_0 = \text{init}$  and  $\forall 0 < k \leq n, a_k \in \mathcal{I}$ . The widgets, to which a scenario reacts, are equal to the widgets to which the last widget in the scenario reacts -  $l(A) = l(a_n)$ .

The set of scenarios is generated by starting with the initial scenario, containing only the initial function  $S_0 = \{\text{init}\}$  and prolonging it iteratively by each widget, where the user can take an action. This is terminated once all  $i \in \mathcal{I}$  are included in at least one scenario. Formally: For  $n > 0, S_{n+1} = \{p \in S_n, x \in l(p) \cup \mathcal{I}\}$

Based on the scenario sets Zhang and Zhao [ZZ19] define the following coverage criteria:

- Each set  $S_n$  of test scenarios should be tested.
- For each given  $S_n$ , each  $p \in S_n$  should be tested.
- For each given  $p$ , each  $w \in l(p)$  should be tested. That is, there should be a test case for each widget that may be modified after the scenario  $p$ .

.. example, which will be implemented here in vue and described in sec xyz.

## 2.3 Scenario Testing

Scenario testing, was originally introduced in Kaner [Kan03] and later as Kaner [Kan13]. The author defines scenarios as hypothetical stories, which aid a person in understanding a complex system or problem. Scenario tests are tests, which are based on such scenarios. [Kan13, p. 1] Further, [Kan03, pp. 2–5] defines five characteristics, which make up a good scenario test as follows: A Scenario test must be

- based on a story - based on a description of how the program is being used
- motivating - stakeholders have interest in this test succeeding and would see to it's resolution
- credible - probable to happen in the real world



- complex - complex use, data or environment
- easy to evaluate - it should be easy to tell if the test succeeded or failed based on the results

Kaner [Kan13] describes the biggest advantages of scenario testing to be - understanding and learning the product in early stages of development(1), connecting of testing and requirement documentations(2), exposing shortcomings in delivering of desired benefits(3), exploration of expert use of the program(4), expose requirement related issues(5).

## 2.4 Behavior-Driven Development

Behavior-Driven Development (BDD), pioneered by North [Nor06] is a software development process, that combines principles from Test-Driven Development and Domain-Driven design [EE04].

Its main goal is to specify a system in terms of its functionality (i.e. its behaviors) with a simple domain-specific language (DSL) making use of English-like sentences. This stimulates collaboration between developers and non-technical stakeholders and further results in a closer connection between acceptance criteria for a given function and matching tests used for its validation.

BDD splits a user story into multiple scenarios, each formulated in the form of *Given*, *When*, *Then* statements, respectively specifying the prerequisite/context, event and outcomes of a scenario.

[TODO] example here

At present ... there based on the division of behavior descriptions and behaviors. Such as Jest/Jasmine combine behavior descriptions and behaviors into one, whereas as Cucumber uses a DSL named Gherkin to specify the behavior descriptions and provides a set of tools to generate behaviors.

### 2.4.1 the other one(forgot name)

splitting into ...

### 2.4.2 Gherkin Language

## 2.5 Model-View-ViewModel

Model-View-ViewModel (MVVM) is a design pattern, which helps in creating a clear separation between business and presentation logic and User interface (UI) of an application. [Bri17, pp. 7–9]

In MVVM there are three core components - the view, model and view model. Those components are clearly separated from each other - the view is aware of the view model and the view model is aware of the model. However, this does not hold in reverse - the model is unaware of the view model and the view model is unaware of the view.

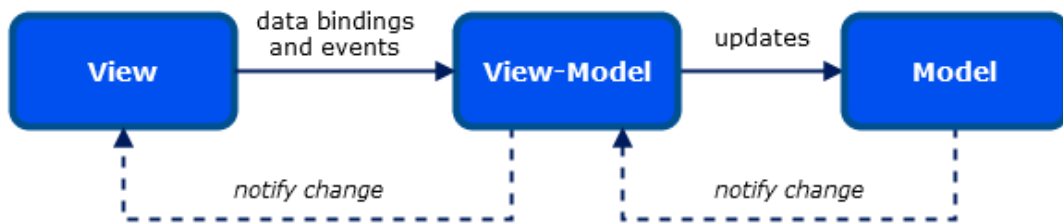


Figure 2.1: MVVM design pattern overview, adapted from [Bri17, p. 7]

### 2.5.1 View

The view is what the user sees. It is responsible for the structure, layout and appearance of the application.

### 2.5.2 View-Model

The view model implements event handlers and properties, to which the view can bind to. It also notifies the view of any changes to the underlying data. It defines the functionality, offered by the UI, but the view determines how it is presented.

### 2.5.3 Model

The model encapsulates the data of the application and validation its logic.

## 2.6 Vue.js

Vue.js [vue21a] is a progressive front end framework for building user interfaces and single-page applications based on the MVVM design pattern described in 2.5 [Mac18] [21a].

### 2.6.1 Components

At the core of Vue.js are components, which are small, self-contained, composable and often reusable custom elements. Almost any type of application can be represented as a tree of components [21a].

In more concrete terms, a Vue.js component is a single file with the extension of *.vue*, which consists of a *template*, *script* and optional *style* part. The *template* is a HTML-based template, which can be parsed specification compliant browsers and HTML parsers. It can contain other components or html elements and is equivalent to the *view* in MVVM.

The *code* section of a Vue.js component includes the view-model of the component. It has a special json object *data*, which is equivalent to the MVVM model. The *script* part of a computed includes css-like styles.

data binding is a general technique that binds data sources from the provider and consumer together and synchronizes them.

### 2.6.2 Reactivity

... enables data binding

### 2.6.3 Directives

Vue.js enables one way bindings(from source - data to target - component or html tag) via the *v-bind* (line X,Y) or *moustache* syntax (line Z). Bindings can contain expressions (line X,Y).

Two way binding can be achieved using the *v-model* directive (line,X,Y,Z). Event handlers can be bound by the method name or also expressions.

### 2.6.4 Data Binding

Vue.js provides support for various forms of Data Binding via a special syntax. Both the data and computed objects of a *Vue.js* component are reactive

Via a special syntax *Vue.js* - one way - two way - event bindings - inline expressions - computed properties

### 2.6.5 Vue.js directives

### 2.6.6 Structure of a Component

(template, code etc.)

bindings two way, one way

g - data - computed properties

template part code part bindings

## 2.7 ESLint

ESLint [21b] is a linting tool (linter) for ECMAScript/JavaScript. Linters are static code analysis tool, which can be used to flag and potentially automatically fix common code issues and enforce consistent code styling.

### 2.7.1 Architecture

At a very high level, ESLint consists of

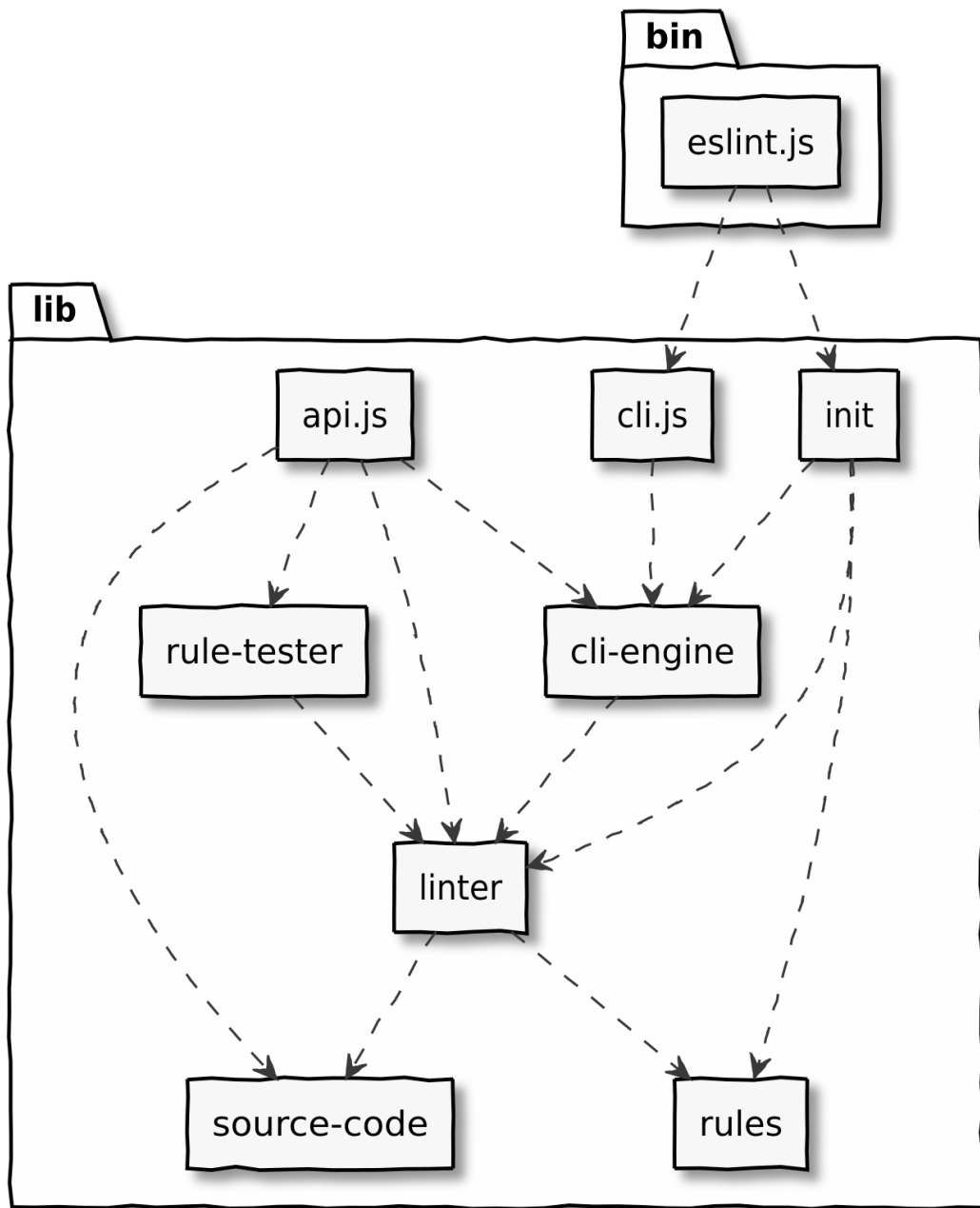


Figure 2.2: ESLint Architecture taken from [21c]

## 2.8 Rules

At the core of ESLint are rules. Rules are extensible pieces of code, bundled as plugins, which can be used to verify various aspects of code. An example would be a rule, which checks for matching closing paranthesis. Each rule consists of a *metadata* object and a *create* function. The metadata object includes metadata such as documentation strings, the type of the rule and whehter it is fixable or not.

Based on type, rules can be either *suggestions*, *problems* or *layout*. Suggestions indicate some

improvement, but are not required and would not cause the linting to fail. Problems on the other hand would result in a linting failure. Layouts are rules that care mainly about the formatting of code, such as whitespaces, semicolons, etc.

If the *fixable* property is specified, it indicates that the errors reported by this rule can be automatically fixed. This can be applied via the `--fix` command line option. It has two possible values - *code* or *whitespace* indicating the type of fixes, that this rule would apply. For example in Integrated development environments (IDEs) fixable *code* errors would show a fix shortcut displayed next to them and *whitespace* rules could be applied when saving the file.

The *create* function of rules takes as arguments a *context* and returns an object of methods which are called by ESLint for each node based on the Visitor pattern while traversing the Abstract syntax tree (AST). ESLint provides a very powerful matching mechanism for specifying what nodes to match called selectors [21d] inspired by estools [est21a].

TODO custom architecture image

TODO what are selectors

TODO what does context provide?

### 2.8.1 AST Explorer

An incredibly useful tool when working with ASTs is AST Explorer, developed by Kling [Kli21]. It enables the exploration of syntax tree generated by various parsers and also includes the vue-eslint-parser [vue21b]

### 2.8.2 ESTree AST

By default ESLint uses the [esl21] parser to parse JavaScript source code into an AST as defined by ESTree specification [est21b]. When Parsing *.vue* files ESLint uses this parser for the code inside the *<script>* tag.

### 2.8.3 ESLint Parser Vue AST

In order to parse the *<template>* section of *.vue* files, ESLint uses the vue-eslint-parser [vue21b]. This parser outputs an AST compliant with their own ASTspecification, defined in [vue21c].

So what if there is text here?

Appendix A

Appendix

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