Detecting Violations of CSS Code Conventions

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Abstract

Code conventions are meant to preserve code base consistency and express preference of a particular programming style. Often, code conventions are expressed in natural language and it is a responsibility of the developers to read, understand and apply them. Typically, developers need to ensure that their code complies to a given style guide manually. There are a number of tools that can automatically detect violations of conventions. However, current solutions remain rigid, laborious or with limited scope. This thesis presents a tool that solves this problem. The proposed solution consists of a domain–specific language that expresses custom CSS conventions and an interpreter of the language capable of finding violations automatically.

First, the need for CSS conventions is evaluated based on whether CSS is still handcrafted. Second, existing CSS code conventions are discovered and analyzed. Third, a domain-specific language capable of expressing existing CSS code conventions is designed. The thesis contains a specification of the designed language and an implementation of its interpreter that detects violations automatically.

Chapter 1

Introduction

Code conventions put constraints on how code should be written in the context of a project, organization or programming language. Style guides can comprise conventions that refer to whitespacing, indentation, code layout, preference of syntactic structures, code patterns and antipatterns. They are mainly used to achieve code consistency, which in turn improves the readability, understandability and maintainability of the code [1, 2, 3].

Style guides are often designed in an ad hoc manner. Coding conventions typically live in documents that contain a description of each rule in natural language accompanied by code examples. This is the case with the style guidelines of Mozilla [4], Google [5], GitHub [6], WordPress [7] and Drupal [8]. It is the responsibility of the developers to ensure that their code complies to a given style guide. Typically, they need to read and understand the conventions and then apply them manually. Such an approach introduces a number of issues. First, using natural language can make guidelines incorrect, ambiguous, implicit or too general. Second, the fact that developers apply conventions manually increases the chances of introducing violations accidentally. There are a number of tools that can automatically detect violations of conventions, however, current solutions are often hard to customize or are limited to one type of violations, e.g. only whitespacing.

The core idea behind the project is to provide a solution that lets developers express an arbitrary set of coding conventions and detect their violations automatically. Writing conventions in an executable form could assist authors in detecting incorrect, ambiguous or inconsistent guidelines. Automatic detection of violations could minimize the effort required by developers to write code that complies to the guidelines. To meet the constraints of a Master's project, the implementation is limited to the domain of Cascading Style Sheets (CSS). The project requires determining the need for CSS code conventions in organizations, collecting and analyzing available style guides, and providing a way to express conventions. Specifically, the project attempts to answer the following set of questions:

Research Question 1 Do developers still maintain plain CSS?

Research Question 2 What code conventions for CSS exist?

Research Question 3 How to express existing CSS code conventions?

The thesis is organized as follows. Chapter 2 provides information about previous studies and defines concepts and terms used throughout the thesis. Chapter 3 presents the research approach used to determine whether CSS is handcrafted and analysis of the gathered results. Chapter 4 contains the research method used to discover existing code conventions and the results of the research. The design and validation of the DSL are presented in Chapter 5. Chapter 6 concludes the thesis.

Chapter 2

Background

This chapter provides background information for concepts used in the thesis. First, a brief definition of ontologies is presented and the main constructs of the Bunge-Wand-Weber are listed. Second, the concept of ontological analysis is introduced and the main types of ontological discrepancies are defined.

2.1 Bunge-Wand-Weber ontology

A **conceptualization** is an abstract, simplified view of the world that is represented for some purpose [11]. It consists of the concepts that are assumed to exist in some area of interest and their relationships [11]. An **ontology** is an explicit specification of a conceptualization [11]. It describes what is fundamental in the totality of what exists and it defines the most general categories to which we need to refer in constructing a description of reality [12].

Researchers distinguish between different kinds of ontologies. For example, based on the specificity of their constructs ontologies can be top-level and domain-specific [12]. Ontologies of the former type are highly general and provide the theoretical foundations for representation and modeling of systems. Ontologies of the latter type define concepts and their relations only for a particular domain. A domain-specific ontology is based on a specific top-level ontology if it uses the categories defined by the high level ontology [12].

The Bunge-Wand-Weber (BWW) ontology [13] is a high-level ontology used in the representation model developed by Wand and Weber [9]. Table 2.1 presents a selected set of the ontological constructs in the BWW ontology.

2.2 Ontological analysis

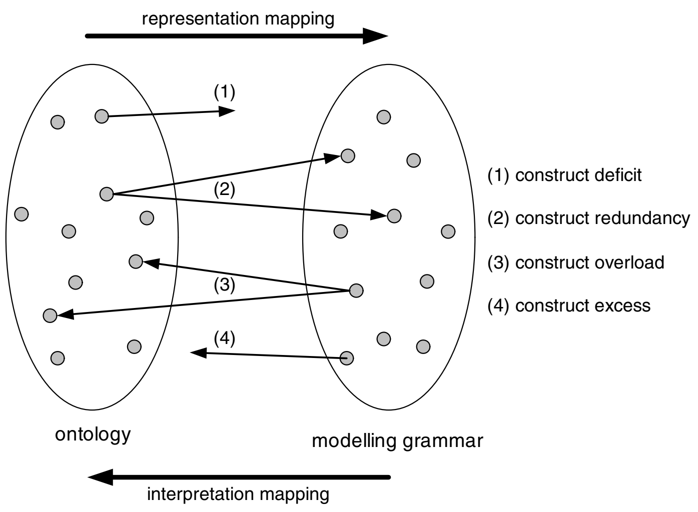
Ontological analysis is an established approach for evaluating the quality of software engineering notations [14]. It consists of a two way comparison between a set of modeling grammar constructs and a set of ontological constructs. The **interpretation mapping** compares the notation with the ontology and the **representation mapping** compares the ontology with the notation [15]. The underpinning of ontological analysis is that modeling grammars are incomplete if they are not able to represent what exists in reality [16]. Furthermore, the analysis requires one-to-one mapping between the modeling grammar and the ontological constructs. Any deviation from such correspondence leads to a discrepancy (Figure 2.1).

Construct deficit occurs when an ontological construct does not have a corresponding construct in the modeling grammar. **Construct redundancy** is observed when a single ontological construct maps to more than one modeling grammar construct. **Construct overload** appears when a modeling grammar construct corresponds to more than one ontological construct. **Construct excess** emerges when a modeling grammar construct does not map to any ontological construct. [14]

Table 2.1: Selected ontological constructs in the BWW representation model

Ontological construct	**Explanation**
Thing	The elementary unit in the BWW ontological model. The real world is made up of things. A composite thing may be made up of other things (composite or primitive). [9]
Properties	Things possess properties. A property is modeled via a function that maps the thing into some value. A property of a composite thing that belongs to a component thing is called an hereditary property. Otherwise it is called an emergent property. A property that is inherently a property of an individual thing is called an intrinsic property. A property that is meaningful only in the context of two or mode things is called a mutual or relational property. [9]
State	A vector of values for all property functions of a thing. [9]
Event	A change of state of a thing. It is affected via a transformation. [9]
Transformation	A mapping from a domain comprising states to a codomain comprising states. [9]
History	The chronologically ordered states that a thing traverses. [10]
Coupling	A thing acts on another thing if its existence affects the history of the other thing. The two things are said to be coupled or interact. [9]
Class	A class is a set of things that can be defined via their possessing a characteristic property. [10]
Subclass	A set of things that can be defined via their possessing the set of properties in a class plus an additional set of properties. [10]
System	A set of things is a system if, for any bi-partitioning of the set, couplings exist among things in the two subsets. [9]
System Composition	The things in the system are its composition. [9]
System Environment	Things that are not in the system but interact with things in the system are called the environment of the system. [9]

Figure 2.1: Ontological Analysis [17, p.92]



Chapter 3

Evaluating the Need for CSS Code Conventions

This chapter focuses on the question whether CSS is still handcrafted. In the Research Method section the used research approach is presented. The Results section contains a summary of the obtained data. The Analysis section comprises a discussion of possible issues with the research method and an interpretation of the results.

3.1 Research Method

Despite the new features added in the second [18] and third [19] versions of CSS, the language has obvious limitations, for example, lack of variables. A number of preprocessors have evolved to tackle the downsides of CSS. Solutions such as SASS [20], LESS [21] and Stylus [22] offer enhanced or even different syntax and translate it to CSS. Preprocessors are not only ubiquitously recommended, but also widely adopted in practice. The presence of such solutions poses the question whether conventions for CSS are required at all. If nowadays CSS is generated and not maintained, the need for CSS conventions is substituted with need for preprocessor conventions.

To determine whether CSS is still handcrafted, all commits to open source repositories hosted on GitHub for the period Jan–Apr 2015 were analyzed. To differentiate between plain CSS and preprocessor code, the extensions of all files in the commits were inspected. In case the commit contains a file with extension `.scss`, `.sass`, `.less` or `.styl`, it is considered preprocessor maintenance. In case the commit contains files with the `.css` extension and no preprocessor extensions, it is considered maintenance of plain CSS. Since the main objective of the search is finding maintained files, only files that have been modified are taken into consideration. Files that have been added are excluded from the results, since developers often add third-party CSS libraries to their repositories.

3.2 Results

To find repositories that contain a commit in the time internal January–April 2015, GitHub's public dataset available on Google BigData[1] was used. As a result, a total of 2,331,864 public repositories were found. While the majority of these repositories were analyzed successfully, 16% of the cases could not be processed. Specifically, 253,611 repositories have been made private since April and are no longer available for download. Additionally, 123,822 repositories were of extremely large size and could not be handled due to memory constraints. As a result, 83.8% of the repositories were analyzed successfully, 10.9% are no longer in the public space, and 5.3% are extremely large (Figure 3.1).

In the period from January to April 2015, a total of 2,282,788 commits that maintain any form of CSS were made to the successfully analyzed repositories. The number includes commits that contain both preprocessors and plain CSS. More than half of them, specifically 1,340,217 of these commits

[1] `https://bigquery.cloud.google.com/`

Figure 3.1: Number of analyzed repositories

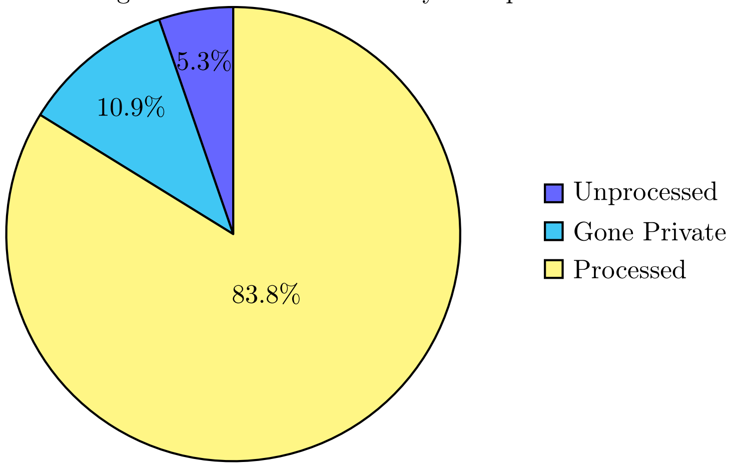
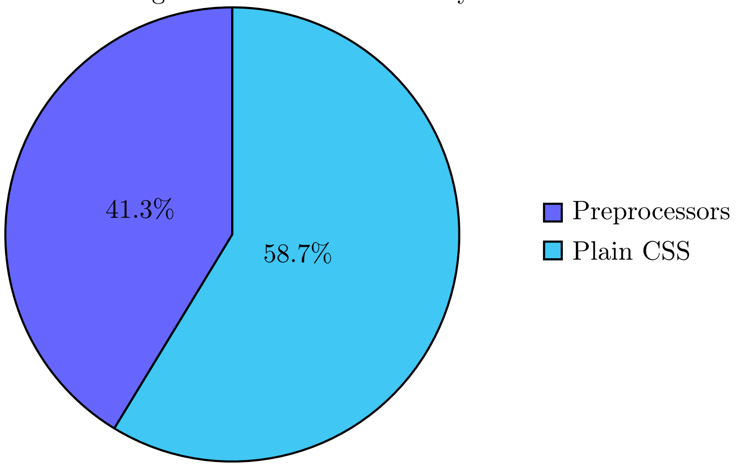


Figure 3.2: Number of analyzed commits



maintain plain CSS, while the rest of the commits contain at least one preprocessor file. As a result, 58.7% of all CSS related commits are still maintenance of plain CSS (Figure 3.2).

3.3 Analysis

There are a number of limitations that need to be considered before interpreting the results of the conducted research. First, the search is conducted on a single hosting platform — GitHub. That said, currently GitHub reports having over 10 million users and 24 million repositories [6], which makes it the largest code host in the world [23]. Second, the search is narrowed to the publicly available repositories. Thus, it lies on the premise that there is not a significant difference between the public and private repositories hosted on the platform. Third, the search detects only the four most popular preprocessor extensions and omits other preprocessors. It is possible that a number of custom preprocessors are used in practice. However, it is assumed that the number of such commits would not increase the number of total CSS commits to the extent at which the percentage of plain CSS commits is significantly diminished.

Having the above limitations in mind, the search provides evidence to conclude that despite of the popularity of preprocessors, plain CSS is still handcrafted on GitHub in the beginning of 2015.

Chapter 4

Discovering Existing CSS Code Conventions

This chapter focuses on determining what CSS code conventions exist. The Research Method section presents the approach used to discover existing CSS conventions. The Results section contains a summary of the gathered conventions.

4.1 Research Method

The primary organization responsible for the specification of CSS has not published an official CSS style guide. As a result, the CSS community has produced a pool of coding conventions, best practices, guidelines and recommendations.

To discover existing CSS code conventions, two searches with the keywords `CSS code conventions` were made using the search engines duckduckgo[1] and google[2]. The first 100 results of each search were analyzed. From each result only conventions that refer to plain CSS are taken into account and conventions related to preprocessors are ignored. In case the result contains links to other style guides, these references are considered as results and analyzed separately.

While searching for conventions, a number of issues were discovered. First, some of the conventions do not provide sufficient information to be applied in practice. Such an example is the convention *Do not use CSS hacks — try a different approach first* when the style guide does not define the meaning of CSS hacks. Such overgeneralized conventions were omitted from the results.

Another part of the discovered conventions introduce a discrepancy between their description in natural language and the provided code example. An instance of such contradiction is when the convention *Nothing but declarations should be indented* is followed by a code snippet illustrating that rules in media queries should also be indented. In such cases the convention is interpreted as described by the code example.

When conventions are not supported with code examples, their description could remain open for interpretation. For example, *Rules with more than 4 selectors are not allowed* could be seen as forbidding multi-selectors with more than four selectors, or disallowing selectors with more than four simple- selectors. All possible interpretations of ambiguous conventions were registered as separate conventions.

There are conventions that are not explicitly stated, but could only be inferred by the other rules. For example, the convention *You can put long values on multiple lines* states that a long value is allowed to appear on several lines. However, this rule implies the presence of another convention, that is not explicitly stated. It implies that short values should appear on one line and only lengthy values are allowed to appear on multiple lines. Such implicit conventions were registered as explicit conventions.

[1]http://duckduckgo.com
[2]http://google.com

4.2 Results

As a result of the searches, 28 CSS style guides were discovered. Sources of these conventions include CSS professionals, open-source communities and companies, such as Google, GitHub, Wordpress, Drupal. Most of the discovered CSS convention sets are parts of bigger style guides and contain a small number of conventions 5–10. Standalone CSS style guides contain from 10 to 42 conventions. The total number of conventions in the discovered style guides is 471. However, style guides often share the same conventions and even refer to one another. Because of this overlapping, only one third of the 471 conventions are unique.

Thus, the result of the searches is 155 unique code conventions appearing in 28 CSS style guides. Some of the most popular conventions are listed below:

- Put a ";" at the end of declarations.
- Do not put quotes in URL declarations.
- Use short hex values.
- Use the shorthand margin property.
- Do not use units after 0 values.
- Use a leading zero for decimal values.
- Avoid qualifying ID and class names with type selectors.
- Use short hexadecimal values.
- When possible, use em instead of pix.
- Avoid using z-indexes when possible.
- Require compatible vendor prefixes.
- Do not use id selectors.
- Id and class names should be lowercase.
- All values except the contents of strings should be lowercase.
- HTML tags should be lowercase.
- Use single quotes in charsets.
- Use single quotes in attribute selectors.
- Put one space between the colon and the value of a declaration.
- Put one space between the last selector and the block.
- One selector per line.
- Forbid empty rules.
- A vendor-prefixed property must be followed by a standard property.
- No trailing spaces.

The full list of all discovered conventions along with their sources and explanation of their meaning is available in the CssCoco GitHub repository[3], expressed in the form discussed in the next chapter.

[3] `https://github.com/boryanagoncharenko/CssCoco/blob/master/analysis.md`

Chapter 5

Expressing CSS Code Conventions

This chapter introduces CssCoco – a domain–specific language capable of expressing CSS conventions. First, the convention corpus is analyzed and the meaning of conventions is made explicit. Second, the abstract and concrete syntax of CssCoco are defined. Third, an implementation of the language interpreter is presented. Finally, the solution is validated using ontological analysis.

5.1 Analysis of conventions corpus

Code conventions is an umbrella term that comprises rules for whitespacing, comments, indentation, naming, syntax, code patterns, programming style, file organization, etc. To gain an overview of the type of conventions used in the CSS domain, all conventions in the corpus are organized in groups depending on the type of constraints they impose. The following three categories were defined (sublists provide examples of conventions that fall in each category):

Layout category contains rules that constrain the overall layout of the code. It includes conventions related to whitespace, indentation and comments. Examples include:

- Use four tabs for indentation.
- Put one blank line between rulesets.
- Disallow spaces at the end of the line.

Syntax Preference category comprises conventions that express preference of a particular syntax. Note that rules in this category do not aim at ensuring CSS validity, but choose between syntactic alternatives. For example, both single and double quote strings are valid in CSS and a convention may narrow down the choice of the developer to single quotes. Examples include:

- Use lowercase for id and class names.
- Require a semicolon at the end of the last declaration.
- Use strings with single quotes.

Programming Style category consists of conventions that put constraints on how CSS constructs are used to achieve a certain goal. They specify preferred code patterns or anti-patterns. Conventions in this group are used mainly to improve maintenance and performance, or to avoid issues in a particular implementation. Examples are:

- Do not use the universal selector.
- Avoid using !important.
- A vendor-prefixed property must be followed by a standard property.

Conventions in each of the groups were analyzed and their violations were made explicit. While the violations of most of the conventions are obvious, some of them require knowledge about the grammar of CSS. For example, conventions such as *Avoid id selectors* directly describe their violations — id selectors. That said, the convention *Use single quotes in URLs* has two violations that are valid CSS code: URLs with double quotes and URL without quotes.

After the violations of each convention were made explicit, the specific actions needed to detect these violations were determined. Currently, the detection of violations is performed by developers manually or with the partial help of tools. To perform such checks, developers need to understand different concepts, e.g. the concept of a rule, HTML element, ID, etc. and perform certain actions, such as find a structure, evaluate a constraint, etc. The analysis tries to grasp the specific concepts and actions used to find violations. To illustrate the process, the analysis of one convention is included. Analysis of all conventions in the corpus is available at the CssCoco GitHub repository [1].

Convention: Disallow empty rules.

Author: CSS lint

Violations: Presence of rulesets that do not contain declarations. In case at least one declaration is present, the ruleset does not violate the convention. Examples include:

```
.myclass { }               /* violation */
.myclass { /* Comment */ } /* violation */
.myclass { color: green; } /* no violation */
```

Actions: Recognize rulesets and declarations. Determine whether a ruleset does not contain any declarations.

The convention aims at getting rid of one type of refactoring leftovers — rulesets without declarations. Removing empty rulesets reduces the total size of CSS that needs to be processed by the browser. One possible approach for discovering violations of the convention at hand is to search the stylesheet for rulesets and then check whether each ruleset contains a declaration. To perform this search successfully, developers need to understand the concept of a ruleset and a declaration, i.e. they need to be able to recognize these two CSS structures. Further, developers need to determine relations between structures, particularly, whether a ruleset contains a declaration.

After all conventions were analyzed, the specific actions and concepts were used to extract requirements and draw conclusions about the needed functionality. First, every convention can be represented as a combination of constraints, regardless of the way it is expressed. There are two major constructs used to convey conventions in natural language: forbid and require. Conventions that forbid describe directly their violations. For example, the convention *Disallow @import* specifies that import statements are violations. Conventions that use the latter construct describe a pattern and once the pattern is found, a constraint is evaluated. In case the constraint is not met, a violation is discovered. For example, the convention *Class names should be lowercase* requires finding class nodes and then checking whether they are lowercase.

As the three categories of conventions imply, conventions can reference nodes from the abstract syntax tree, concrete syntax tree and parse tree [24] of CSS. For example, the convention *A rule must not contain width and padding declarations* accesses concepts that are present in the abstract syntax tree. Similarly, the rule *Put a semicolon at the end of the last declaration* refers to nodes that are omitted by the abstract syntax tree and are present in the concrete syntax tree. All whitespacing and indentation conventions target nodes that are relevant only to the parse tree of CSS.

Usually, the patterns described in conventions target one of all described nodes. For example, when the pattern refers to rulesets in media queries, the target node is the ruleset and the media query is part of the context. Similarly, when a pattern describes a ruleset that contains a float declaration, the target node is the ruleset and the float declaration is only a context constraint. Certain conventions can have more than one target nodes, e.g. when two declarations in a ruleset need to be compared.

[1] https://github.com/boryanagoncharenko/CssCoco/blob/master/analysis.md

Conventions refer to nodes using their type or function in the CSS program. For example, in the snippet `[class=‘‘test’’]` the node test can be selected 1) because it is of type string and 2) because it is an attribute value. Similarly, a node with value `#ffffff` may be selected because it is a hexadecimal value or because it represents a color.

Conventions may use CSS-specific knowledge. For example, the rule *Use lowercase for properties; vendor-prefixed properties are exception* requires differentiating between standard and vendor-specific properties. While in this case the two types of properties can be easily distinguished, some conventions require information that cannot be obtained using the CSS code. Consider the convention *Order vendor-prefixed values by their version; newer versions of vendor values should appear after old ones.* To detect violations for this convention the release dates of the properties need to be available for comparison.

Conventions rarely target a single node. Typically, they refer to a number of nodes organized in a pattern. For example, the convention *A ruleset must not contain display and float declarations* requires searching for two specific declaration that appear under the same parent node. The nodes in the pattern do not have to be immediate relatives. In fact, they can be scattered across the tree. For example, the rule *Do not use more than 5 @font-face declarations* requires searching for specific nodes that appear anywhere in the tree.

5.2 CssCoco DSL

5.2.1 Syntax overview

To express the conventions in the corpus, the domain-specific language CssCoco is proposed. It is a declarative language that has two main constructs: conventions and contexts. Conventions express the specific rules that have to be enforced on the code and contexts describe the CSS nodes that need to be ignored while searching for violations.

The language constructs that define conventions try to resemble the way conventions are expressed in natural text. There is a construct that describes directly what is disallowed. For example, the convention *Do not use import statements* is expressed in the following way:

```
forbid import
message 'Do not use import statements.'
```

The keyword *forbid* is followed by a description of the node that is disallowed. In the current convention, we only need to state its type — import. Each convention requires a message clause. The string after the *message* keyword will be displayed to the user when a violation is found.

As the domain analysis indicates, conventions are often expressed as a pattern that, if found, needs to meet given constraints. In CssCoco syntax such conventions are defined using the `find ... require ...` construct. For example, the convention *All class names should be lowercase* is described as follows:

```
find c=class
require c.name match lowercase
message 'All class names should be lowercase'
```

The find clause in the above rule specifies the pattern that needs to be found and the require clause states the constraint that should be applied to the discovered nodes. Note that to refer to a matched node in the require clause, the node should be assigned an identifier (`c` in the above example).

Conventions can put more constraints on a node description in the pattern. For example, the convention *Use a leading zero for decimal values* requires finding all nodes of type number that have a numeric value in the interval [-1, 1]. Such constraints are expressed as curly brackets immediately after the type of the node.

```
find n=number{num-value < 1 and num-value > -1}
require n.string match '^0.*'
message 'Use a leading zero for decimal values'
```

Conventions can describe patterns that consist of more than one node. For example, the rule *Use single quotes in charsets* can be expressed in the following way:

```
find s=string in charset
require s.has-single-quotes
message 'Use single quotes in charsets'
```

The pattern contains the description of two nodes: first, a node that is of type string and a node of type charset. The `in` keyword in the pattern description indicates that the string node is nested in the charset node. In this way, the pattern will match only the strings that appear in a charset.

In CssCoco, conventions are grouped in contexts that specify what nodes should be ignored when searching for patterns. For example, often when rules refer to newlines they completely disregard indentation. The convention *Every declaration must be on a new line* requires a newline to be present immediately before the declaration. However, when declarations are indented their immediate previous sibling is an indentation node. To handle such cases, the language uses contexts that explicitly describe the ignored nodes.

```
Whitespace
ignore indent
{
    find d=declaration
    require newline before d
    message 'Put every declaration on a new line'
}
```

Contexts have a user-defined name and an optional ignore clause. The `ignore` keyword is followed by a description of the nodes that need to disregarded.

5.2.2 Abstract syntax

This section describes the abstract syntax of the designed domain-specific language. An overview of the abstract syntax is presented in Figure 5.1, followed by detailed views of each of the subclasses.

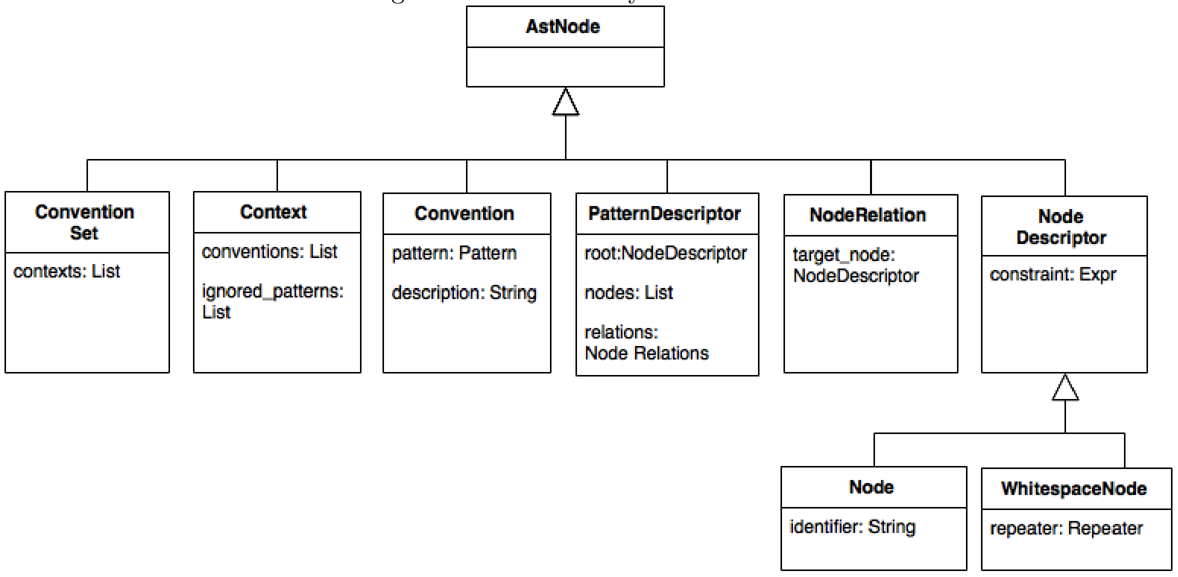
ConventionSet represents a style guide. It comprises a number of conventions that form coherent guidelines. Attribute `contexts` is a list of Contexts that contains contexts.

Context represents a group of conventions that belong to the same semantic group (e.g. whitespacing, syntax preference, programming style). Attribute `conventions` is a list of Conventions that contains conventions. Attribute `ignored_patterns` is a list of Patterns that are ignored while searching for the target pattern. For example, while searching for violations of semantic conventions, the whitespacing and indentation nodes are ignored.

Convention represents a rule that enforces specific constraints. Attribute `pattern` is the pattern that the convention targets. Attribute `description` is the description of the convention in natural text. This description is displayed to the user when a violation of the convention is discovered.

PatternDescriptor represents a description of a node or a combination of related nodes that given convention constraints. Attribute `root` is the top node described in the pattern. Attribute `nodes` is a collection of all nodes described by the pattern. Attribute `relations` is a collection of relationships between the nodes used in the pattern.

Figure 5.1: Abstract Syntax Overview



NodeDescriptor is an abstract class that contains a description of a Css Node. Attribute `constraint` is an expression that designates the constraints applied to the node.

Node represents a description of a node used in a PatternDescriptor. Attribute `constraint` is an expression that designates constraints applied to the node. Attribute `identifier` is a given string that can be used as a reference to the matched node.

WhitespaceNode represents a description of a whitespace node that references space, newline, indentation symbols. Attribute `constraint` is an expression that designates constraints applied to the node. Attribute `repeater` is an optional constraint that specifies the number of times a whitespace node can appear consecutively. Repeaters are useful to express conventions that do not specify exact quantities of whitespace symbols. For example, the convention "put at least one blank line between rules" sets a lower limit of the number of blank lines, but not an upper limit.

NodeRelation represents a relation between two Nodes. Attribute `target_node` designates a description of the Node targeted by the relation.

A detailed view of the expressions in the abstract syntax of CssCoco is presented in Figure 5.2. Following is a description of the subclasses of Expression:

LiteralExpr represents an expression containing a literal value. Attribute `value` is the value of the literal expression.

VariableExpr represents a reference to a matched node. Attribute `name` is the identifier used to reference the node.

UnaryExpr represents expressions with a single operand. Attribute `operand` is operand of the expression.

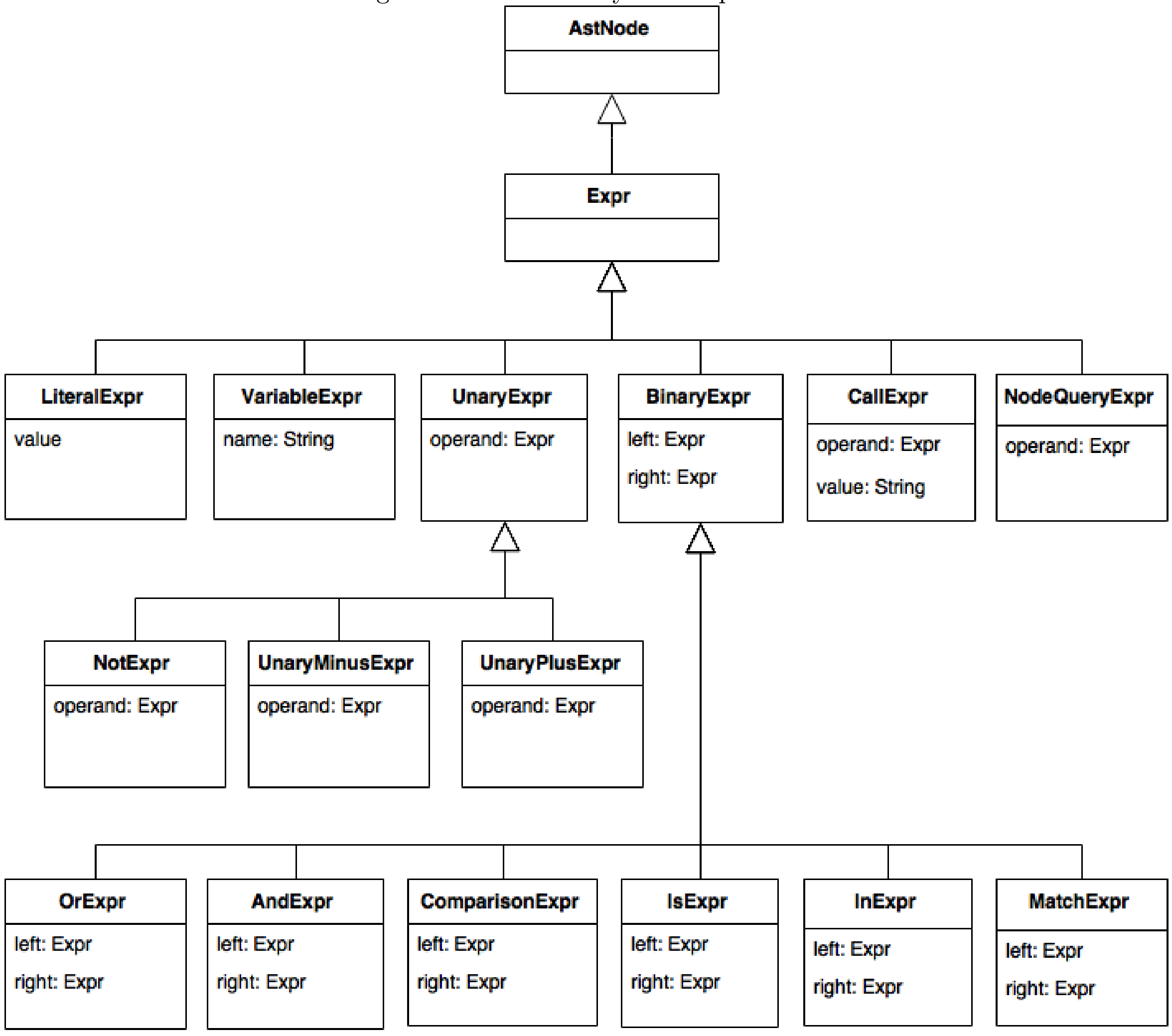
NotExpr represents negation expression.

UnaryMinusExpr represents unary minus expression.

UnaryPlusExpr represents unary plus expression.

BinaryExpr represents expressions with two operands. Attributes `left` and `right` represent the first and second operands, respectively.

Figure 5.2: Abstract Syntax Expressions



OrExpr represents disjunction expression.

AndExpr represents conjunction expression.

ComparisonExpr represents expression that compares two operands.

IsExpr represents expression that checks whether the first operand is of the given type, specified by the second operand.

InExpr represents expression that checks whether the first operand is present in a list of values, specified by the second operand.

MatchExpr represents expression that checks whether the first operand matches a regular expression, specified by the second operand.

CallExpr represents expression that invokes a API property or method of the operand. Attribute `operand` is the operand of the expression. Attribute `value` is the name of the API property or method that is invoked.

NodeQueryExpr represents expression that queries node context. Attribute `operand` is the node used as a reference point for the query.

Figure 5.3: Abstract Syntax Literal Expressions

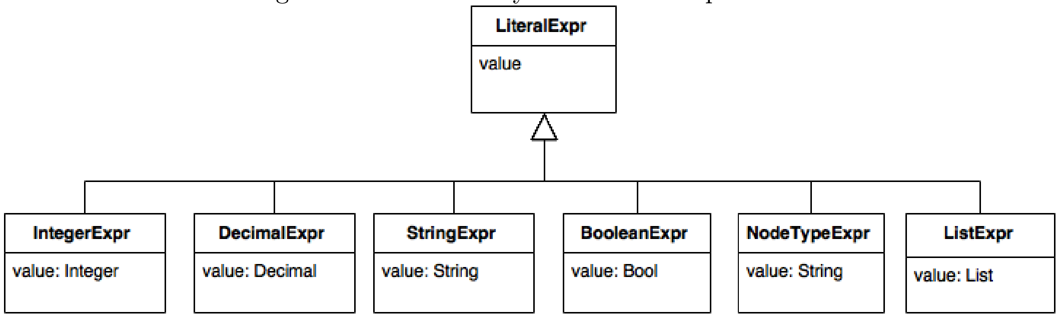


Figure 5.3 presents a detailed view of the literal expressions used in the abstract syntax of CssCoco. Following is a listing of the classes.

IntegerExpr represents expression containing an integer value.

DecimalExpr represents expression containing a decimal value.

StringExpr represents expression containing a string value.

BooleanExpr represents expression containing a boolean value.

ListExpr represents expression containing a list value. The elements of the list are of type LiteralExpr.

NodeTypeExpr represents expression containing a string value that describes a node type.

Figure 5.4: Abstract Syntax Literal Expressions

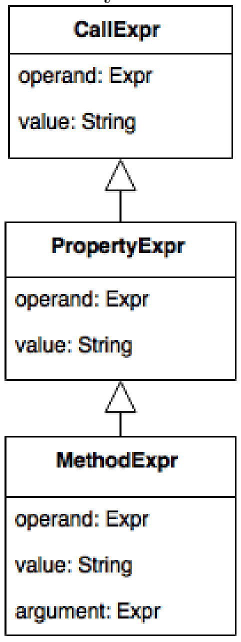


Figure 5.4 presents a detailed view of the call expressions used in the abstract syntax of CssCoco. Following is a listing of the classes.

PropertyExpr represents an expression that returns the value of a property of the operand node. Attribute `operand` represents the node targeted by the expression. Attribute `value` holds the name of the property that is accessed.

MethodExpr represents an expression that invokes a method of the operand node. Attribute `argument` represents the argument passed to the invoked method.

Figure 5.5: Abstract Syntax Node Query Expressions

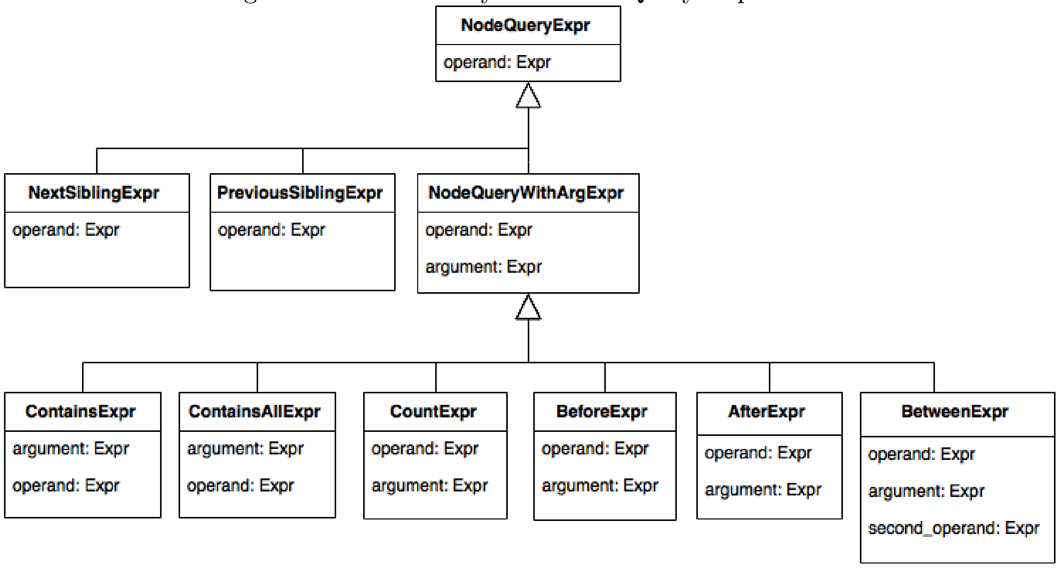


Figure 5.5 presents an overview of the Node Query Expressions. The following listing describes the subclasses in details:

NextSiblingExpr represents expression that returns the following sibling of the operand node.

PreviousSiblingExpr represents expression that returns the previous sibling of the operand node.

NodeQueryWithArgExpr represents expression that queries node context and uses additional constraints for the query. Attribute `argument` represents the additional constraints used by the query.

ContainsExpr represents an expression that checks whether the operand node contains a node that matches given constraints.

ContainsAllExpr represents an expression that checks whether the operand node contains nodes that match given constraints.

CountExpr represents an expression that counts the number of ancestor nodes of the operand that match a given constraint.

BeforeExpr represents an expression that checks whether a given pattern of nodes appears before the operand node.

AfterExpr represents an expression that checks whether a given pattern of nodes appears after the operand node.

BetweenExpr represents an expression that checks whether a given pattern of nodes appears between the two operand nodes.

5.2.3 Concrete syntax

This section contains the concrete syntax of the designed DSL. Below are presented the grammar rules accompanied by the mapping to the abstract syntax of the language.

stylesheet represents a style guide.

Abstract Syntax Mapping: ast.ConventionSet.

```
stylesheet : context* ;
```

context represents a group of logically related conventions. A single style guide can comprise a number of conventions that enforce various constraints, e.g. whitespacing, syntax preference, program style. Contexts group conventions that ignore the same nodes while searching for their violations.

Abstract Syntax Mapping: ast.Context.

```
context : Identifier ignore_clause? '{' convention* '}' ;
ignore_clause : 'ignore' (node_descriptor)+ (',' (node_descriptor)+)* ;
```

convention represents a single rule in the style guide. Conventions are typically expressed by directly stating what is disallowed or describing a condition that if met, requires additional constraints. The former way of expressing conventions is represented by the `forbid` conventions. The latter approach uses the structure `find ... require ...`. To break down complex disallowing conventions, the structure `find ... forbid ...` has been introduced. This aims at improving readability of conventions. Additionally, the find conventions have a where clause which applies constraints for matching nodes. It is used to expression matching constraints that span over multiple nodes and therefore cannot be present in the node descriptors.

Abstract Syntax Mapping: ast.Convention.

```
convention : 'forbid' pattern 'message' String
           | 'find' pattern ('where' logic_expr)? ('require'|'forbid') logic_expr 'message' String
           ;
```

pattern represents a pattern of nodes and their relations. For example, it can describe a horizontal sequence of sibling nodes, a vertical pattern of nested nodes, or pairs of elements with a common parent.

Abstract Syntax Mapping: ast.PatternDescriptor.

```
pattern : node_declaration (('in'|'next-to') node_declaration)*
        | fork ('in' node_declaration)*
        ;
fork : '(' node_declaration (',' node_declaration)+ ')' ;
node_declaration : (Identifier '=')? semantic_node ;
```

node_descriptor represents a description of a node. It describes the type of the node and its additional constraints.

Abstract Syntax Mapping: ast.NodeDescriptor.

```
node_descriptor : 'unique'? node_type ('{' (logic_expr|repeater) '}')? ;
repeater : Integer ',' Integer? | (',')? Integer ;
```

logic_expr represents expressions that perform logic operations and glue arithmetic and type expressions.

Abstract Syntax Mapping: ast.NotExpr, ast.AndExpr, ast.OrExpr and all arithmetic_expression and type_expression mappings.

```
logic_expr : '(' logic_expr ')'
           | 'not' logic_expr
           | logic_expr 'and' logic_expr
           | logic_expr 'or' logic_expr
           | type_expr
           | arithmetic_expr
           ;
```

type_expr represents expressions that ensure node type and perform node queries on nodes. They are located in a separate parser rule because they interpret Identifiers as node type expressions instead of a API calls.

Abstract Syntax Mapping: ast.IsExpr, ast.BeforeExpr, ast.AfterExpr, ast.BetweenExpr.

```
type_expr : arithmetic_expr operator='is' Identifier
          | node_descriptor+ ('before' | 'after') type_operand
          | node_descriptor+ 'between' type_operand 'and' type_operand
          ;
type_operand : Identifier | semantic_node ;
```

arithmetic_expr represents arithmetic, comparison, set membership and regex expressions. These are located in a separate parser rule because they interpret identifiers as API calls instead of node type expressions.

Abstract Syntax Mapping: ast.UnaryMinus, ast.UnaryPlus, ast.LessThan, ast.LessThanOrEq, ast.GreaterThan, ast.GreaterThanOrEq, ast.Equal, ast.NotEqual, ast.InExpr, ast.MatchExpr, ast.LiteralExpr.

```
arithmetic_expr : ('-'|'+') arithmetic_expr
                | arithmetic_expr ('<'|'>'|'<='|'>='|'=='|'!=') arithmetic_expr
                | arithmetic_expr ('in'|'not in'|'match'|'not match') arithmetic_expr
                | call_expression
                | element
                ;
element : Boolean | Decimal | Integer | String | list_ ;
```

call_expression represents an API call expression and also node query expression.

Abstract Syntax Mapping: ast.CallExpr and ast.NodeQueryExpr.

```
call_expression : call_expression '.' call_expression
                | Identifier ('(' (element | semantic_node ) ')')?
                ;
```

Boolean: represents Boolean literal expression.

Abstract Syntax Mapping: ast.BooleanExpr.

```
Boolean : 'true' | 'True' | 'false' | 'False' ;
```

String: represents String literal expression.

Abstract Syntax Mapping: ast.StringExpr.

```
String : "'" (EscapeSequence | ~['])*? "'" ;
EscapeSequence : "\\" "'" ;
```

Integer: represents Integer literal expression.

Abstract Syntax Mapping: ast.IntegerExpr.

```
Integer : (ZeroDigit | NonZeroDigit Digit*) ;
Digit : ZeroDigit | NonZeroDigit ;
NonZeroDigit : [1-9] ;
ZeroDigit : [0] ;
```

Decimal: represents Decimal literal expression.

Abstract Syntax Mapping: ast.DecimalExpr.

```
Decimal : ( NonZeroDigit Digit* | ZeroDigit? ) '.' Digit+ ;
Digit : ZeroDigit | NonZeroDigit ;
NonZeroDigit : [1-9] ;
ZeroDigit : [0] ;
```

list and **list_element** represent the List literal expression.

Abstract Syntax Mapping: ast.ListExpr.

```
list_ : '[' list_element (',' list_element)* ']' ;
list_element : Integer | Decimal | String | semantic_node ;
Letter : [a-zA-Z] ;
Identifier : (Letter)(Letter|Digit|'_'|'-')* ;
```

type_expression represents the NodeType literal expression.

Abstract Syntax Mapping: ast.NodeType.

```
node_type : '(' node_type ')'
          | 'not' node_type
          | node_type 'and' node_type
          | node_type 'or' node_type
          | Identifier
          ;
```

5.2.4 Proof of Concept

To study the feasibility of the designed language, a proof of concept was developed. The implemented solution consists of two parts: a standalone Python package and a plug-in for Sublime Text editor.

The first part of the designed solution comprises the CssCoco interpreter. The implementation is done in Python and currently contains 13 000 lines of code. The source code is available at CssCoco GitHub repository [2]. The solution was also added to the Python Package Index (Pypi) repository [3] and for less than month it has accumulated over 5000 downloads. The package offers a `csscoco` command that takes as arguments a .css and a .coco files and returns a list of the discovered violations.

The current implementation of the CssCoco interpreter is available only for Python 3.4. Additionally, the proof of concept requires nodejs. This dependency is added because the only existing CSS parser that produces CSS parse trees with the required level of details is implemented in nodejs.

The second part of the proof of concept brings the functionality implemented in the Python package to Sublime Text editor. The plug-in uses the `csscoco` command to find violations in CSS files that are being edited in the text editor. Currently, the plug-in is implemented for Sublime Text 3. The source code of the solution is publicly available at a separate GitHub repository [4].

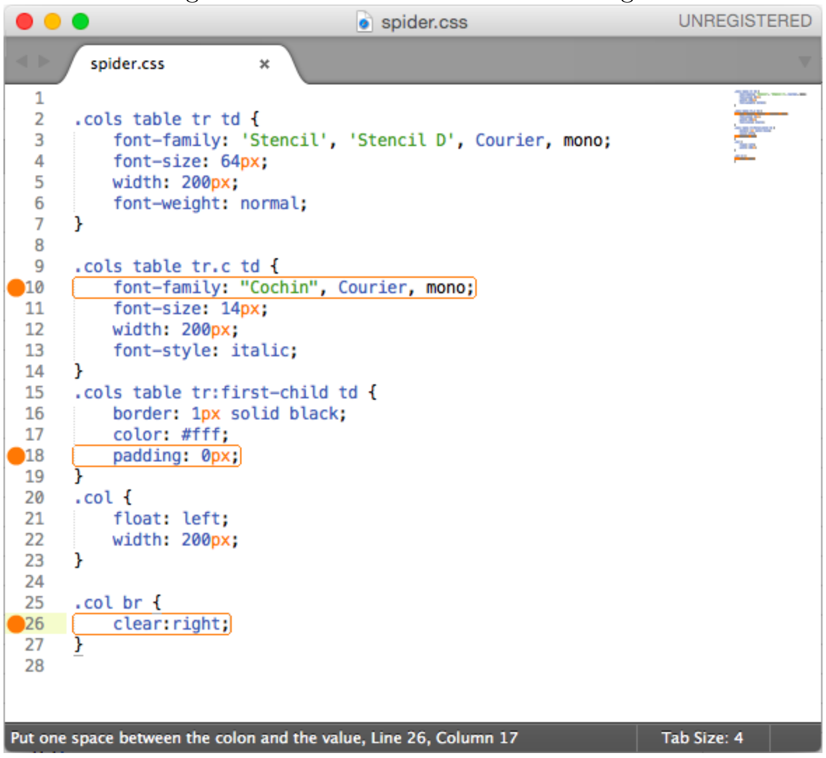
The plug-in offers a command that finds and visualizes violations. Similarly to other linter tools, rows that contain violations are marked with a color border and a gist appears at the side bar. When the cursor is positioned on a line that contains a violation, the error message is displayed in the status bar. For example, on Figure 5.6 the cursor is placed on line 26 and the status bar indicates that there should be one space between the colon and the value of the declaration.

The proof of concept leaves some of the features of the language not implemented. Specifically, it does not include the following:

- Unique construct. A small portion of the conventions require the unique construct. The feature is not included in the current version and is left for future implementation.
- Ordering rules. To check for violations of conventions that specify ordering, requires efficient implementation especially for large CSS files. The feature is currently not supported because of time constraints.
- Indentation rules. Conventions that refer to indentation specify relative indentation. For example, when a convention states that the contents of a ruleset should be indented, this implies that they should be indented once compared to the beginning of the ruleset. Detecting violations of such conventions is laborious and is left for future implementation.
- Dictionary. A number of the conventions require usage of a dictionary. The feature is not included in the current version and is left for future implementation.

[2] https://github.com/boryanagoncharenko/CssCoco
[3] https://pypi.python.org/pypi?:action=display&name=csscoco
[4] https://github.com/boryanagoncharenko/Sublime-CssCoco

Figure 5.6: CssCoco Sublime Text Plug-in



```
 1
 2  .cols table tr td {
 3      font-family: 'Stencil', 'Stencil D', Courier, mono;
 4      font-size: 64px;
 5      width: 200px;
 6      font-weight: normal;
 7  }
 8
 9  .cols table tr.c td {
10      font-family: "Cochin", Courier, mono;
11      font-size: 14px;
12      width: 200px;
13      font-style: italic;
14  }
15  .cols table tr:first-child td {
16      border: 1px solid black;
17      color: #fff;
18      padding: 0px;
19  }
20  .col {
21      float: left;
22      width: 200px;
23  }
24
25  .col br {
26      clear:right;
27  }
28
```

```
Put one space between the colon and the value, Line 26, Column 17        Tab Size: 4
```

5.3 Validation

The method chosen for validating the designed domain-specific language is ontological analysis, since it is a widely accepted way for evaluating software notations [25, 16, 14, 26, 10]. The particular approach used for conducting ontological analysis consists of several steps. First, a domain-specific ontology is designed. Second, the ontology is used as a reference point for the interpretation and representation mappings. Third, emerged anomalies are analyzed and conclusion about the quality of the notation is made.

5.3.1 Ontology design

The first stage of validation requires designing a domain-specific ontology. The domain of the developed ontology is limited to detecting violations of CSS code conventions. In other words, the designed ontology tries to capture only the concepts that exist when an agent searches a CSS stylesheet for violations of given set of code conventions.

The designed domain-specific ontology is based on the BWW top-level ontology [13], i.e. it uses the high-level categories of the BWW ontology to describe the objects, concepts and entities in the specific domain. The rationale behind the decision to use the BWW ontology is that it is the leading ontology used for ontological analysis [14]. The main ontological constructs used in the BWW ontology are listed in section 2.1.

The designed ontology is presented using several approaches. As recommended by Wand and Weber, the ontology is described using a dictionary comprising definitions of entities in natural text and, second, using Backus-Naur Form (BNF) notation [9, 27]. Additionally, a system diagram is included to provide a better view of the couplings between the different entities. The ontology is intentionally not presented using Unified Modeling Language or Entity-Relationship diagrams. These modeling languages are subjects of ontological analysis themselves and therefore are not suitable for expressing an ontology.

Following is a list with the main concepts discovered in the domain along with their descriptions.

The used BWW concepts are in *italics* and the domain-specific concepts are in **bold**.

Class **Style Guide** describes the coding practices adopted in the context of a single project, organization, community or language. An individual Style Guide is a *composite thing* built of Conventions. Conventions in a Style Guide are interpreted together to form a coherent set of guidelines.

Property **Conventions** refers to the conventions contained in the Style Guide.

Class **Convention** is a specific rule that imposes constraints on the CSS code. Conventions are the building blocks of Style Guides. An individual Convention is a *composite thing* that contains a Context.

Intrinsic Property **Description** contains the reasoning behind the Convention.

Hereditary Property **Ignored Constructs** denotes the description of constructs that should be ignored while searching for the Convention's Context. It is inherited by the Context thing that builds a Convention.

Class **Context** is a description of a **Pattern** that the Convention forbids. An individual Context is a *composite thing* that comprises a Constraint or a **Constraint Combinator**. A violation is discovered when a Pattern in the current stylesheet fulfills all constraints specified by the Constraint or the Constraint Combinator.

Property **Ignored Constructs** are descriptions of Patterns that need to be disregarded while searching for the current Context. In fact, the property denotes a collection of Contexts.

Class **Constraint Combinator** is an entity that connects logically Constraints or other Constraint Combinators. An individual Constraint Combinator is a *composite thing* that comprises one or more logically related Constraints and/or Constraint Combinators.

Property **Number of Subjects** denotes the number of logically related Constraints and/or Combinators that are combined.

Property **Combinator Type** is the particular way the Constraints are combined.

Subclass **Negation Constraint Combinator** is a type of combinator that takes one Constraint or Combinator and returns the opposite Constraint or Combinator. An individual Negation Constraint Combinator is a *composite thing* that comprises one Constraint or Combinator.

Property **Number of Subjects** denotes the number of logically related Constraints and/or Combinators that are combined. In the case of the Negation Constraint Combinator, the Number of Subjects property is equal to one.

Property **Combinator Type** is the particular way the Constraints are combined. Specifically, this type of combinator negates the Constraint or Combinator it takes.

Subclass **Disjunction Constraint Combinator** is a type of combinator that takes two or more Constraints or Combinators and combines them using the OR logical operator. An individual Disjunction Constraint Combinator is a *composite thing* that comprises two or more subjects.

Property **Number of Subjects** denotes the number of logically related Constraints and/or Combinators that are combined.

Property **Combinator Type** is the particular way the Constraints are combined. Specifically, this type of combinator states that at least one of the Constraints it combines need to be fulfilled.

Subclass **Conjunction Constraint Combinator** is a type of combinator that takes two or more Constraints or Combinators and combines them using the AND logical operator. An individual Conjunction Constraint Combinator is a *composite thing* that comprises two or more subjects.

Property **Number of Subjects** denotes the number of logically related Constraints and/or Combinators that are combined.

Property **Combinator Type** is the particular way the Constraints are combined. Specifically, this type of combinator states that all of the Constraints it combines need to be fulfilled.

Class **Constraint** is a specific restriction that needs to be fulfilled. They are used in a **Context** to build a description of a **Pattern**. Constraints are individual requirements that are imposed on Subjects. Based on the value of the requirement, there are different types of Constraints represented below as *subclasses.*

Property **Subject** indicates the thing that is being constrained.

Property **Requirement** denotes the particular limitation applied to the Subject.

Subclass **Existence Constraint** is a type of Constraint that requires existence of the subject.

Property **Subject** indicates the thing that is being constrained.

Property **Requirement** denotes the particular limitation applied to the Subject. Specifically, the requirement is that the Subject must exist.

Subclass **Comparison Constraint** is a type of Constraint that compares the subject to another value.

Property **Subject** indicates the thing that is being constrained.

Property **Requirement** denotes the particular limitation applied to the Subject. Specifically, the requirement is that the Subject must be related to the Value in a given way.

Property **Value** denotes the value that is used for the comparison.

Subclass **Type Constraint** is a type of Constraint that checks whether the subject is of a given type.

Property **Subject** indicates the thing that is being constrained.

Property **Requirement** denotes the particular limitation applied to the Subject. Specifically, the requirement is that the Subject must be of the given type.

Property **Value** denotes the type that the subject should meet to satisfy the constraint.

Subclass **Textual Form Constraint** is a type of Constraint that imposes restrictions on the textual representation of the subject.

Property **Subject** indicates the thing that is being constrained.

Property **Requirement** denotes the particular limitation applied to the Subject. Specifically, the requirement is that the Subject must be equal to the given Value.

Property **Value** denotes the textual form that the Subject should meet for the constraint to be satisfied.

Subclass **Set Membership Constraint** is a type of Constraint that requires the subject to be a member of a set.

Property **Subject** indicates the thing that is being constrained.

Property **Requirement** denotes the particular limitation applied to the Subject. Specifically, the requirement is that the Subject must be a member of the Value.

Property **Value** denotes the set that the subject should be present at for the constraint to be satisfied.

Class **Literal Value** is a thing that represents a constant value. It includes numbers, strings, boolean values, etc.

Property **Value** denotes the specific value possessed by the literal.

Class **Violation Log** is the final product of a violations search. An individual Violation Log is a composite thing that contains Violations.

Property **Number of Violations** indicates the size of the Violation Log.

Class **Violation** A Violation occurs when a Pattern that matches the Context of a Convention is found.

Property **Description** explains in natural text what causes the Violation. Typically, the Description is extracted from the Convention that the Violation breaks.

Property **Position in Stylesheet** indicates the location of the Pattern that violates the Convention in the Stylesheet.

Class **Stylesheet** is the CSS code that needs to be checked for compliance with the Style Guide. An instance of Stylesheet is a composite thing that comprises a number of **Constructs**.

Property **Checked** indicates whether a Stylesheet has been checked for compliance to a given Style Guide.

Class **Construct** is a part of the Stylesheet. It can refer to nodes in the CSS abstract syntax tree, concrete syntax tree and parse tree. Examples include whitespacing, indentation, comments, colons, delimiters, rulesets, declarations, etc.

Property **Property** encapsulates properties of nodes specific to the CSS domain. For example, the type and the string representation of the node are its properties. Similarly, specific CSS Nodes can expose properties that are tightly coupled to the CSS domain, such as release date or vendor name of a CSS property.

Class **Pattern** is a particular part of the CSS that matches the description of a Context. An instance of a Pattern is a composite thing built from one or many Constructs.

Property **Number of Constructs** denotes the constructs that are contained in the Pattern.

Event **Search for Violations in Stylesheet** occurs when the developer completes the search for violations in a Stylesheet, a Violation Log is created and the state of the Stylesheet is altered. When the search is completed, the Stylesheet is considered checked for compliance to the Style Guide.

New State **Violation Log** { Violations = value }

New State **Stylesheet** { Checked = True }

Event **Context (Convention) Discovered** occurs when the Context of a convention is discovered and a Violation is recorded in the Violation Log. The state of the Violation contains its description and position in Stylesheet.

New State **Violation** { Description = value, Position in Stylesheet = value }

Event **Stylesheet modified** occurs when the Constructs in the Stylesheet are modified. The state of the Stylesheet is changed to not checked for compliance.

New State **Stylesheet** { Checked = False }

Event **Style Guide modified** occurs when any of the parts of a Style Guide are modified. This event changes the state of the Stylesheet to not checked for compliance.

New State **Stylesheet** { Checked = False }

Most of the definitions in the ontology refer to simple concepts that appear in the code conventions domain. For example the concept of a Style Guide refers to a collection of coherent conventions. A Style Guide on its own does not have any emergent or intrinsic properties and, thus, it is defined through the conventions it comprises. Note that in reality a Style Guide may contain a number of intrinsic properties, for example it may have an author and contributors. Such properties, however, are not considered part of the specific domain, and thus lie outside the scope of the ontology.

A Convention is defined as the building block of a Style Guide. However, the ontological concept of a Convention is slightly different than what is used as a convention in the domain analysis section. For example, domain analysis indicates that there are two types of conventions: forbid and require. The former type of conventions describes directly their violations. The latter type describes a pattern that, if found, puts additional requirements that must be met. In case these requirements are not met, a violation is discovered. For example, the violation *Do not use id selectors* tells that id selectors are violations. The convention *Strings should be with single quotes* states that strings must have single quotes, and a violation is discovered if the found string does not. These convention types are not related to the meaning of conventions but to the way they are expressed. A convention with the same meaning could be expressed using both structures: *Strings should be with single quotes* and *Forbid strings with double quotes*. Since ontological concepts are concerned with the meaning of things and have to be independent of the language used to express them, the ontology does not possess subclasses of Convention.

A Context is a description of things that are disallowed by a Convention, i.e. it states explicitly what Patterns violate a Convention. In this sense, the meaning of a Convention is always expressed through the possible violations of that Convention. A Context aims at describing a whole violation pattern and consists of a single Constraint or a number of logically related Constraints. A Constraint is a requirement that has to be fulfilled. Constraints can be combined into complex constraints using Constraint Combinators. Since a Context may describe both a simple pattern that can be expressed through a single constraint and a complex pattern that imposes a number of constraints, the Context can comprise either a Constraint or a Combinator.

As its name suggests, a Constraint Combinator is used to combine Constraints. That said, Constraint Combinators could be recursive constructs and combine other Combinators. The Number of Subjects property denotes the number of Constraints or Combinators that the current Combinator connects. For example, the Negation Constraint Combinator always has a single subject, while the Conjunction and Disjunction Constraint Combinator have two or more subjects. The Combinator Type property indicates the particular operation used to combine the subjects. Based on the value of this property, there are three subclasses of Combinators: Negation, Disjunction and Conjunction that correspond to the logical operators `not`, `or` and `and`, respectively.

A Constraint refers to a single specific requirement. Every Constraint has a subject and a requirement. The subject is the object that is being constrained and the requirement refers to the specific limitation that is applied to the subject. There are different types of Constraints based on the value of the requirement property. For example, a Comparison Constraint requires the subject to be equal or greater than a given value and the Type Constraint requires the subject to be of a particular type. The Existence Constraint requires the subject to exist.

Since Conventions are used to constrain CSS code, subjects are typically Constructs or their properties. A Construct denotes a concrete part of the Stylesheet, e.g. newline, semicolon, declaration, ruleset, etc. Each Construct exposes a number of properties that are tightly coupled to its function in the stylesheet. For example, a property construct has properties that indicate whether it is vendor-specific and its release date.

Patterns are composed of Constructs. The Constructs in the Pattern do not need to form a coherent valid Stylesheet and they do not have to be adjacent or directly related. In fact, they could be scattered across the whole Stylesheet. Patterns denote the concrete Constructs that match the description provided by the Context of a Convention. In this sense, they are the specific instances of Violations.

Definitions of the ontological concepts in the listing above often state that an instance of a class is a composite thing that consists of other things. To provide a better understanding of the way composite things are constructed, the same concepts are also expressed using BNF notation:

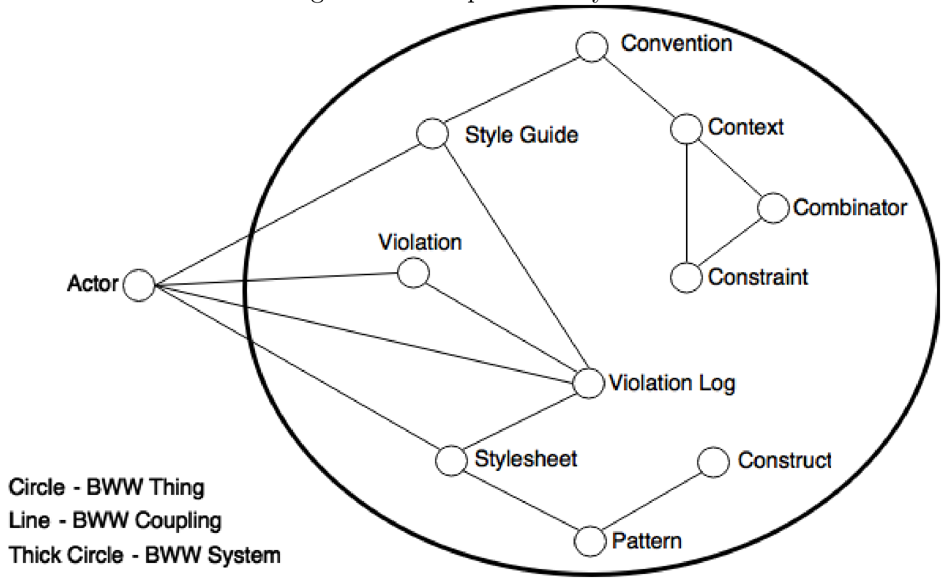
```
style_guide    ::= convention+
convention     ::= context
context        ::= combinator | constraint
combinator     ::= (negation_combinator | disjunction_combinator | conjunction_combinator
                 | constraint)+
violation_log  ::= violation*
stylesheet     ::= construct+
pattern        ::= construct+
```

The grammar above illustrates that a Style Guide needs to contain one or more Conventions. A Convention consists of a Context, which in turn, comprises either a Combinator or a Constraint. Because a Context describes the whole pattern that is considered a violation, it can be expressed through a single constraint or a combination of logically related constraints. A Combinator is a recursive construct that can comprise Constraints or other Combinators. Different subclasses of

Combinator have different constraints on the number of subjects they combine. In general, they require at least one subject. A Violation Log could exist without any Violations in the cases when a Stylesheet is checked for conformance to a Style Guide and no violations are discovered. Both Stylesheet and Pattern are defined through 1 or more Constructs. Note that the concept of Stylesheet does not map to a CSS file, but to the whole CSS code that needs to be processed. This is why a Stylesheet requires at least one Construct in order to exist.

While the above grammar presents the composition of things, it does not illustrate how things interact with each other. To provide a better understanding of the dynamics between things defined in the ontology, a graph of the system is presented in Figure 5.7.

Figure 5.7: Graph of the system



According to the theory, a coupling occurs when the existence of a given thing affects the history of another thing and, in turn, history is defined as the chronological ordered states that a thing traverses [13]. Thus, in the domain-specific ontology a coupling exists between the Style Guide and the Convention things, because the existence of a Convention alters the state of the Style Guide. Similarly, a Context changes the state of a Convention. Because a Constraint can appear both in a Context and a Combinator, it affects their states. In turn, a Combinator alters the state of a Context. Thus, couplings exist between the Constraint, Combinator and Context.

There are also couplings between Construct, Pattern and Stylesheet things. Both Stylesheet and Pattern are composed of Constructs, and thus affected by their existence. Since a Pattern is a specific occurrence of a combination of Constructs, it is also coupled to Stylesheet.

A Violation is coupled to a Violation Log, since the presence of a new a Violation alters the state of the log. Further, a Violation Log contains information about the violations of a particular Style Guide that occur in a specific Stylesheet. In this sense, a Violation Log is a function of a Style Guide and a Stylesheet and it is coupled to both things.

There are a number of external events that can change the state of the system. An actor can initiate search for violations, which affects the state of the Violation Log and the Stylesheet. If during the search an actor discovers a violation, the state of the Violation is altered. Also, an actor can modify the Stylesheet and the Style Guide. Thus, couplings exist between the Actor and the Stylesheet, Violation, Violation Log and Style Guide.

5.3.2 Ontological analysis

The ontological analysis is a bidirectional mapping between the designed domain-specific ontology and the domain-specific language. It consists of two mappings: representation and interpretation [14]. The former mapping matches the ontology to the language and the latter — the language to the ontology.

Typically, ontological analysis is used to compare the abstract syntax of the language constructs to the concepts of an ontology. However, the designed ontology contains concepts that fall outside the scope of the abstract syntax. For example, the notion of Violation Log has a corresponding class in the system, but that class denotes the product of the violations search and is not part of the abstract syntax. The particular approach chosen to conduct ontological analysis is to compare the abstract syntax of the language to the ontology. Additionally, all remaining ontological constructs are mapped to their representation in the whole system. For example, the ontological concept of a Violation Log is matched with the Violation Log class in the analysis module.

5.3.2.1 Representation and Interpretation Mappings

This subsection contains the two mappings between the modeling grammar and domain-specific ontology. Table 5.2 presents the representation mapping. The left-hand side of the table contains the ontological constructs in the order of definition and the right-hand side comprises the corresponding modeling grammar construct. Table 5.4 presents the interpretation mapping. The left-hand side contains classes from the abstract syntax, followed by classes that have a representation in the ontology and the right-hand side contains the corresponding ontological construct.

Ontological Classes and Subclasses

The ontological concept of Style Guide is represented in the modeling grammar as a Convention Set. Similarly, the notion of Convention maps to the Convention class and the concept of Context maps to the Pattern Descriptor class.

The ontological concept of Constraint Combinator appears in the modeling grammar as a union of expressions: Not Expression, And Expression and Or Expression. The subclasses of Constraint Combinators have refined and more specific mappings. For example, the Negation Constraint Combinator correspond to the Not Expression and the Conjunction and Disjunction Constraint Combinators map to And and Or Expressions, respectively.

The ontological concept of Constraint appears in the modeling grammar as a number of Expressions. These include Expressions used in mappings for the subclasses of Constraint: Comparison Expression, Is Expression, Match Expression, In Expression and Node Query Expression. The mappings for most of the Constraint subclasses are straight forward. For example, the Comparison Constraint is represented as a Comparison Expression and the Type Constraint appears as an Is Expression. Similarly, the Textual Form Constraint is a Match Expression and the Set Membership Constraint maps to the In Expression. That said, the Existence Constraint requires further attention. As defined in the ontology, the Existence Constraint requires the subject to exist. In the modeling grammar this concept is indirectly presented using multiple structures. Nodes in a pattern are specified using two ways: either through using Node Descriptor and Node Relations, or through Node Query Expression. The modeling grammar describes the target nodes from the pattern and their parent nodes using the former approach, and nodes that are nested in the target nodes — using the latter. For example, when the pattern that needs to be matched is a ruleset which contains a z-index property and appears in a media query, the existence of the media query and the ruleset (and their relationship) is described using Node Descriptors and a Node Relation. The existence of the property contained in the ruleset is denoted using a Node Query Expression.

The ontological constructs of Violation Log and Violation are mapped to the Violation Log and Violation classes, respectively. The notion of a Stylesheet is represented by the Stylesheet Node in the solution and a Pattern is mapped to Css Pattern. The concept of a Construct is represented in the abstract syntax tree as a Variable Expression. The reason behind this mapping is that in the modeling grammar Variable Expression denotes only Constructs.

Ontological Properties

The majority of the ontological properties are mapped to a single construct in the solution. For example, the Description property of Convention class in the ontology is directly mapped to the Description property of the Convention class in the modeling grammar. However, some of the property mappings are not that obvious. For example, the ontological property Conventions of class Style Guide is represented by a combination of properties in the solution: Contexts of Convention Set and Conventions of Context. Also, the notion of Ignored Constructs maps to the Context class in the solution. The reason for these mappings comes from the fact that the solution groups together conventions with identical ignored constructs. As stated in the ontology description, each convention specifies a set of constructs that need to be ignored while searching for its violations. For example, while evaluating the constraints of conventions related to newlines, the indentation constructs are typically ignored. Because the ignored constructs are similar for most of the conventions, the modeling grammar groups conventions that use the same ignored constructs into contexts. Thus, the Convention Set contains Contexts and a Context specifies the ignored constructs of all conventions that it contains.

The Number of Subjects property of Constraint Combinator is mapped to the operands of the expressions that correspond to the Constraint Combinator. Similarly, the Subject and the Value properties of a Constraint are mapped to the operands of the expressions that map to Constraint.

The ontological property Violations of the Violation Log construct appears in the modeling grammar as property Violations of the Violation Log class. The Violation class exposes Description and Position properties that map to the ontological properties Description and Position in Stylesheet. The Checked property of Stylesheet does not have a representation in the system. The property Property of Construct is denoted in the abstract syntax using a Call Expression.

5.3.3 Ontological Evaluation of the System

The primary purpose of the representation and interpretation mappings between the ontology and the modeling grammar is to discover discrepancies between the two entities. The four types of ontological anomalies are considered in the following subsections.

5.3.3.1 Redundant Constructs

Construct redundancy is a type of discrepancy in which more than one modeling construct can represent a single ontological construct. The representation mapping illustrates that there are three candidates for this anomaly.

First, the Conventions property of Style Guide is matched to Contexts property of Convention Set and the Conventions property of Context. Such mapping is required since the modeling grammar groups Conventions that share the same Ignored Constructs in a Context. Thus, a Style Guide in the modeling grammar does not possess conventions but a number of Contexts that, in turn, contain conventions. In this sense, the properties Contexts and Conventions together represent the concept of Conventions.

Note that redundancy occurs when the two grammar constructs can independently represent the same ontological concept. In the specific case, however, none of the constructs taken individually can express the property. It is their combination that represents the concept. Mapping a single ontological concept to a combination of modeling grammar constructs is an accepted approach and has been used in multiple studies [15]. Thus, the two constructs are not considered redundant.

Second, the Comparison, Is, In, Match and Node Query Expressions map to the concept of Constraint. As defined in the ontology, a Constraint is a class that has multiple subclasses depending on the specific requirement they enforce. In this sense, Expressions that map to any subclass of Constraint, also map to the Constraint class. This is why, the Constraint corresponds to a union of all mappings of its subclasses. Thus, the expressions are not considered redundant.

Similarly, the Constraint Combinator is mapped to the Not, And and Or Expressions. Again, the mapping is a combination of the individual mappings of the Constraint Combinator subclasses. In this sense, the Expressions are not considered redundant.

Third, the Existence Constraint is mapped to the Node Descriptor, Node Relation and Node Query Expressions. Existence Constraint is a type of Constraint that requires the Subject to exist. For example, the convention *Use a fallback property for RGBA and HSLA values* requires the fallback declaration to have the same property as the matched declaration and the value of the fallback declaration to be different than RGBA or HSLA. However, before these, the convention requires the fallback declaration to exist.

In the modeling grammar, when a Pattern Descriptor refers to multiple nodes, the presence of a Node Descriptor denotes the existence of CSS Node and the Node Relation specifies how the Nodes are connected in the Pattern Descriptor. As described in the domain analysis section, each Pattern Descriptor has one of more target nodes. These are the specific nodes that need to be iterated. While the Node Descriptors and Node Relations describe the target nodes in the Pattern and their parent nodes, the Node Query Expression is used to describe parts of the pattern that are nested in the targets.

As with the previous two cases, the ontological concept cannot be represented by Node Descriptors and Node Relations or by Node Query Expressions taken individually. Their combined use allows expressing patterns. For this reason, the constructs are not considered redundant.

5.3.3.2 Construct Overload

Construct overload emerges when a single modeling construct can represent a number of ontological constructs. In the interpretation and representation mappings every language construct is assigned a single ontological construct. In this sense, there are not candidates for overload discrepancy.

5.3.3.3 Construct Excess

Construct excess is a discrepancy in which a modeling construct does not have a mapping to an ontological construct. In the interpretation mapping all constructs that belong to the abstract syntax are mapped to an ontological construct. Thus, there are not candidates for construct excess from the abstract syntax.

5.3.3.4 Construct Deficit

Construct deficit appears when an ontological construct does not have a corresponding modeling structure. A candidate for such discrepancy is the property Checked of class Stylesheet as it appears without a matching construct in the system. However, maintaining the status of a Stylesheet is considered outside the scope of the system. Such functionality is highly dependent on the specific information offered by the IDE or text editor. Support for this property remains in the environment of the system. In this sense, the candidate is not considered an occurrence of deficit.

5.3.3.5 Results

In this section are presented the interpretation and representation mappings between the modeling grammar and the designed domain-specific ontology. Further, all types of discrepancies are analyzed and argumentation is provided why they should not be considered anomalies. Having the analysis in mind, it can be concluded that the ontological analysis provides sufficient evidence to consider the designed system both ontologically clear and complete.

Ontological constructs	**Grammar constructs**
Style Guide	Convention Set
Conventions (Style Guide)	Contexts (Convention Set), Conventions (Context)
Convention	Convention
Description (Convention)	Description (Convention)
Context	Pattern Descriptor
Ignored Constructs (Context)	Context
Constraint Combinator	Not, Or, And Expression
Number of Subjects (Constraint Combinator)	Operand of Combinator Expressions
Negation Constraint Combinator	Not Expression
Disjunction Constraint Combinator	Or Expression
Conjunction Constraint Combinator	And Expression
Constraint	Comparison, Is, In, Match, Node Query Expressions
Subject (Constraint)	Operand of Constraint Expressions
Value (Constraint Subclasses)	Second Operand of Binary Expression
Existence Constraint	Node Descriptor, Node Relation, Node Query Expression
Comparison Constraint	Comparison Expression
Type Constraint	Is Expression
Textual Form Constraint	Match Expression
Set Membership Constraint	In Expression
Literal Value	Literal Expression
Value (Literal Value)	Value (Literal Expression)
Violation Log	Violation Log
Violations (Violation Log)	Violations (Violation Log)
Violation	Violation
Description (Violation)	Description (Violation)
Position in Stylesheet (Violation)	Position (Violation)
Stylesheet	Stylesheet Node
Checked (Stylesheet)	-
Construct	Variable Expression
Property (Construct)	Call Expression
Pattern	Css Pattern
Number of Constructs (Pattern)	Nodes (Css Pattern)

Table 5.2: Representation mapping

Grammar constructs	**Ontological constructs**
Convention Set	Style Guide
Contexts (Convention Set)	partly Conventions (Style Guide)
Context	Ignored Constructs (Context)
Conventions (Context)	partly Conventions (Style Guide)
Convention	Convention
Description property (Convention)	Description (Convention)
Pattern Descriptor	Context
Node Descriptor	partly Existence Constraint
Node Relation	partly Existence Constraint
Literal Expression	Literal Value
Variable Expression	Construct
Not Expression	Negation Constraint Combinator
And Expression	Conjunction Constraint Combinator
Or Expression	Disjunction Constraint Combinator
Comparison Expression	Comparison Constraint
Match Expression	Textual Form Constraint
In Expression	Set Membership Constraint
Is Expression	Type Constraint
Call Expression	Property (Construct)
Node Query Expression	partly Existence Constraint
Css Pattern	Pattern
Nodes (Css Pattern)	Number of Constructs (Pattern)
StylesheetNode	Stylesheet
Violations Log	Violations Log
Violations (Violations Log)	Violations (Violation Log)
Violation	Violation
Description (Violation)	Description (Violation)
Position (Violation)	Position in Stylesheet (Violation)

Table 5.4: Interpretation mapping

Chapter 6

Conclusion

The variability of CSS conventions used in practice cannot be handled by existing tools. Thus, developers often need to make sure their code complies to a given style guide manually. The thesis offers a solution to this problem. Its contribution is threefold:

1. First, the need for CSS conventions is evaluated through analyzing a total of 1,954,102 public repositories. Results indicate that 58% of all commits that maintain any form of CSS, still maintain plain CSS. The gathered data provides evidence to conclude that despite of the popularity of preprocessors, CSS is still handcrafted on GitHub in the beginning of 2015.

2. Second, to discover existing CSS code conventions two search engines were used and the first 100 results of each search were analyzed. As a result, 28 style guides containing 471 conventions were discovered. Analysis indicates that 155 of the conventions are unique. A list containing the description of conventions, their sources and detailed analysis is presented.

3. Third, a domain-specific language that is capable of expressing the gathered conventions is proposed. A proof of concept consisting of two parts is developed: a standalone Python package and a plug-in for Sublime Text editor. The implementation illustrates that the suggested approach enables automatic detection of violations of CssCoco conventions. The designed language is validated using ontological analysis. A domain-specific ontology, based on Bunge-Wand-Weber top level ontology, is defined and used as a reference in the ontological analysis. The conducted analysis of ontological discrepancies indicates that the language is both ontologically clear and complete.

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Appendices

Appendix A

Concrete Syntax of CssCoco

This appendix contains all rules presented in the Context Syntax section of the Expressing CSS Code Conventions chapter. The following two snippets present the lexer and parser rules, respectively. Both snippets are taken from the grammar file of CssCoco[1].

```
Letter : [a-zA-Z] ;

EscapeSequence : "\\" "'" ;

Digit : ZeroDigit | NonZeroDigit ;

NonZeroDigit : [1-9] ;

ZeroDigit : [0] ;

Boolean : 'true' | 'True' | 'false' | 'False' ;

Identifier : (Letter)(Letter|Digit|'_'|'-')* ;

String : "'" (EscapeSequence | ~[''])*? "'" ;

Integer : (ZeroDigit | NonZeroDigit Digit*) ;

Decimal : ( NonZeroDigit Digit* | ZeroDigit? ) '.' Digit+ ;
```

The parser rules of CssCoco are presented in the next snippet.

[1] https://github.com/boryanagoncharenko/CssCoco/blob/master/csscoco/lang/syntax/coco.g4

```
stylesheet : context* ;

context : Identifier ignore_clause? '{' convention* '}' ;

ignore_clause : 'ignore' (node_descriptor)+ (',' (node_descriptor)+)* ;

convention : 'forbid' pattern 'message' String
           | 'find' pattern ('where' logic_expr)? ('require'|'forbid') logic_expr 'message' String
           ;

pattern : node_declaration (('in'|'next-to') node_declaration)*
        | fork ('in' node_declaration)*
        ;

fork : '(' node_declaration (',' node_declaration)+ ')' ;

node_declaration : (Identifier '=')? semantic_node ;

node_descriptor : 'unique'? node_type ('{' (logic_expr|repeater) '}')? ;

repeater : Integer ',' Integer? | (',')? Integer ;

logic_expr : '(' logic_expr ')'
           | 'not' logic_expr
           | logic_expr 'and' logic_expr
           | logic_expr 'or' logic_expr
           | type_expr
           | arithmetic_expr
           ;

type_expr : arithmetic_expr operator='is' Identifier
          | node_descriptor+ ('before' | 'after') type_operand
          | node_descriptor+ 'between' type_operand 'and' type_operand
          ;

type_operand : Identifier | semantic_node ;

arithmetic_expr : ('-'|'+') arithmetic_expr
                | arithmetic_expr ('<'|'>'|'<='|'>='|'=='|'!=') arithmetic_expr
                | arithmetic_expr ('in'|'not in'|'match'|'not match') arithmetic_expr
                | call_expression
                | element
                ;
element : Boolean | Decimal | Integer | String | list_ ;

call_expression : call_expression '.' call_expression
                | Identifier ('(' (element | semantic_node ) ')')?
                ;

list_ : '[' list_element (',' list_element)* ']' ;

list_element : Integer | Decimal | String | semantic_node ;

node_type : '(' node_type ')'
          | 'not' node_type
          | node_type 'and' node_type
          | node_type 'or' node_type
          | Identifier
          ;
```