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MASTERS PROJECT

Representation Mismatch Reduction for Development in Rules-Based Business Engines

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Declaration of Authorship

I, Paul SPENCER, declare that this thesis titled, "Representation Mismatch Reduction for Development in Rules-Based Business Engines" and the work presented in it are my own. I confirm that:

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Abstract

Graduate School of Informatics

Faculty of Science

Master of Software Engineering

Representation Mismatch Reduction for Development in Rules-Based Business Engines

by Paul SPENCER

Context: Declarative rules engine languages, such as Drools, can become difficult to reason about when there are many rules.

Objective: This project investigates how different projections of the code can ease the comprehensibility of the code.

Method: We created an implementation of the Drools language using the MPS language workbench and made innovative projections of large ASTs.

Results:

Keywords: projectional editing; Rules Engines; MPS; Drools

Paper type: Research paper

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Chapter 1

Introduction

> The limits of my language mean the limits of my world.
>
> *Logico-Tractatus Philosophicus*
> *Ludwig Wittgenstein*

1.1 Problem statement

Miller's Law[1] states that an average human can hold in his short-term memory 5-9 objects. This is often an argument for more succinct code. The argument being anything that is not immediately in the developers vision has to be stored in her memory. With it being impractical to reason about code that she cannot recall, then the fewer relevant items to her reasoning that are out of view the easier it is to reason about the code.

Our host organization, Khonraad Software Engineering, a subsidiary of Visma, provides mission-critical services focussed on the automation of workflows at the cross-section of local government and healthcare. Specifically, Khonraad facilitates the mental health care and coercion laws in the Netherlands - WVGGZ, WZD, and WTH - which provide agencies the ability to intervene in domestic violence, psychiatric disorders, and illnesses.

Khonraad's system facilitates reporting and communication between municipalities, police, judiciary, lawyers, mental health care, and many social care institutions. The system has 15,000 users and is available 24/7.

Configuration and administration use complex matrices of compliance mechanisms, access user rights and communication settings. The sensitivity of the personal data, being both medical and criminal, means security is of utmost importance. The security against data loss, preventing unlawful disclosure and guaranteeing availability, especially during crisis situations, is crucial. Demonstration of the correctness of the, often changing, configuration is a major concern in the company.

This configuration is done in a business rule system, specifically JBoss Drools.

Drools is a language that shares an unfortunate characteristic with many other rules languages. It is verbose and can contain many rules that can interact with each other without obvious visual connection. As Forgy[2] points out, for production systems in general, "production systems have another property that makes them particularly attractive

for constructing large programs: they do not require the programmer to specify in minute detail exactly how the various parts of the program will interact". This property leads to very large and hard to reason about collections of implicitly connected rules.

Reasoning over a small number of rules is already surprisingly hard. Our host organization has many rules and, thus, reasoning about them is particularly challenging.

We have observed the difficulty that developers have trying to reason about and edit collections of Drools files. We hypothesize that developers can be presented with different views on their code that will allow them to better understand the code. The problem we wish to solve - how to improve the ability to reason about large collections of Drools rules - we believe, lends itself to the technique of projectional editing. By using projections to improve feedback whilst coding, we believe that this can reduce the representation impedance mismatch that hampers developer's reasoning.

The problem considered in this thesis is how to present rules to a developer in a way in which she can interact with [TODO: finish this thought]. As is perhaps already obvious it is not our intention to override the will of the language engineers who have spent many years developing this language and it's ecosystem. The goal of this thesis is to augment the current developer experience.

1.2 Research questions

To reason about a large code base of rules engine code effectively, a different presentation is needed. This presentation should allow a clearer organization whilst remaining interactive. We can formulate the following research questions based on the discussion in the preceding sections.

The research question we wish to answer is:

- **Main research question:** "How can projectional editors and DSLs be combined to address feedback mechanisms for developers in the context of reasoning about rules in a rule-based business engine?"

This question requires knowing if it is possible with current tooling, thus we would like to answer the question:

- **RQ 1:** "What is the current state of language workbenches supporting projectional editing?"

Finally, we specifically would like to know how we can improve the ability to reason about the business rules engine, so we ask the question:

- **RQ 2:** "Which projections can help developers to get appropriate feedback about rules?"

1.3 Contributions

This thesis proposes a code representation of business rules in a concise and readable format that could solve comprehensibility issues resulting from large code bases of business rules. The implementation behind the approach relies on language engineering and projectional editing. An implementation has been developed as a stand alone opensource solution on a limited demonstration version of Drools. The underlying Drools implementation can be used as a base language for model to model generation by the wider MPS ecosystem.

1.4 Project context

This investigation was hosted by Khonraad Software Engineering, a subsidiary of Visma. Khonraad provides mission-critical services focussed on the automation of workflows at the cross-section of local government and healthcare. Specifically, Khonraad facilitates the mental health care and coercion laws in the Netherlands - WVGGZ, WZD, and WTH - which provide agencies the ability to intervene in domestic violence, psychiatric disorders, and illnesses.

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This work environment allows us to work on an existing project, where the tangible success will have an impact on the lives of those in critical need. Khonraad has it's own implementations in the Drools language, that have evolved over the iterations of the laws. The evolution of the code base over the years means that the real-life issues we came across are not just thought experiments.

1.5 Thesis outline

We start in chapter 2 with the required background information on projectional editing and rules engines. In chapter **??** we present the research questions. Further, the chapter describes the protocol that we use for search strategy, selecting our studies, extracting data from them, and synthesizing the results. Chapter 4 presents the results of our synthesis of data from the primary studies. This is followed, in chapter 5, by a discussion of both the validity of the work and the implications of the findings. We discuss the implications of this study in chapter 6. Finally, the conclusions are presented in chapter 7.

Chapter 2

Background

This chapter gives the background information required on rules engines and projectional editing. It presents the specific case of rules engine that we will be using for our investigation: Drools. Further, it briefly examines the base tool type for creating domain-specific languages: Language work benches. Finally, it presents the specific projectional editing tool we will be using: JetBrains MPS.

2.1 RulesEngines

2.1.1 What is a rules engine?

In this section we will describe what a rules engine is and a little of its history.

The Aristotelian doctrine of essentialism declares that a thing has properties that are essential and properties that are accidental. If one takes away accidental properties, then the thing remains the thing. If one takes away essential properties, the thing is no longer the thing. If the thing is a business application, then its essential properties are its business rules.

Simply put, business rules are the principles or regulations by which an organization carries out the tasks needed to achieve their goals. When properly defined these rules can be encoded into statements that defines or constrains some aspect of the business organizational behavior. A rule consists of a condition and an action. When the condition is satisfied then the action is performed. More formally, business rules can be seen as the implication in the basic logical principle of Modus Ponens.

When described like this, one could me forgiven for thinking is this not just an if-then logic that is frequently used in traditional programming. One would not be wrong, however in traditional programming, representing all the combinatorial outcomes can become complex. In the typical application architecture, rules are distributed in the source code or database. Each additional rule leads to more fragility.

Documentation describing these rules may be found in the design documentation or user manuals. However, as applications evolve documentation gets out of sync with codebase. Once this desynchronization occurs, to know what the rules that govern the application, one has to navigate the codebase and decode the rules from their, often scattered, locations.

A rules engine is also known as a Business Rules Engine, a Business Rules Management System or a Production Rules System. The goal of a rules engine is the abstraction of business rules into encoded and packaged logic that defines the tasks of an organization with the accompanying tools that evaluate and execute these rules. Simply put, they are where we evaluate our rules. Rules engines match rules against facts and infer conclusions. If we return to the Modus Ponens comparison:

$$\begin{array}{l} p \\ \underline{p \rightarrow q} \\ \therefore q \end{array}$$

If the premise p holds and the implication $p \rightarrow q$ holds then the conclusion q holds. In terms of a rule engine and business rules this could be seen as:

1. the rules engine gathers the data for the premise: p
2. it examines the business rules as the implications: $p \rightarrow q$
3. it executes the conclusion: q

Rules engines follow the recognize-act cycle. First the match, i.e. are there any rules with a true condition, Next the do conflict resolution, to pick the most relevant of the matching rules, finally they act, which is to perform the actions described in the rule. If no items are matched then the cycle is terminated, otherwise the first step is returned to.

Rules Engines are declarative, focussing on the what of the rules not the the how of the execution. Date[3] describes rules engine as to "specify business process declaratively, via business rules and get the system to compile those rules in to the necessary procedural (and executable) code." Fowler[4] describes rules engine as follows: " ... providing an alternative computational model. Instead of the usual imperative model, which consists of commands in sequence with conditionals and loops, a rules engine is based on a Production Rule System. This is a set of production rules, each of which has a condition and an action ...".

Rule engines arose from the expert systems of the late 70s and early 80s. Expert systems initially had three main techniques for knowledge representation: Rules, frames and logic[5]. "The granddaddy" of the expert systems, MYCIN, relied heavily on rules based knowledge representation[6], rather than long inference chains. MYCIN was used to identify bacteria and recommend antibiotic prescriptions. MYCIN and its progenitor, DENDRAL, spawned a whole family of Clinical Decision Support Systems that pushed the rules engine technology until the early 1980's. Research into rules engines died out in the 1980s as it fell out of fashion.

Early in their existence, the rules engines hit a limiting factor because the matching algorithms they used suffered from the utility problem, i.e. the match cost increased linearly with the number of rules being examined/ This problem was solved by Charles Forgy's efficient pattern matching Rete algorithm[2], and its successors. This algorithm works by modelling the rules as a network of nodes where each node type works as a filter. A fact will be filtered through this network. The pre-calculation of this network is what provides the performance characteristics.

The first popular rules engine was Office Production System from 1976 In 1981 OPS5 added the Rete algorithm. CLIPS in .. JESS Drools

Product		Developer	licence type
CLIPS	[7]	NASA	open source
Drools	[8]	JBoss/RedHat	open source
BizTalk Business Rule Engine	[9]	Microsoft	proprietary
WebSphere ILOG JRules	[10]	IBM	proprietary
OpenRules	[11]	OpenRules	open source

TABLE 2.1: Rules Engine products.

In general, rules engines are forward chaining. This means to test if [TODO: Explain forward chaining with logic symbols]

[TODO: ADD MORE HISTORY HERE]

Moving forward to current times, there are a few rules engines currently in use. Some of the more commonly used ones are shown in table 2.1

Some of the advantages of using a rules engine include:

- The separation of knowledge from it's implementation logic
- Business logic can be externalized
- Rules can be human readable

In summary a rules engine, is the executor of a rules based program, consisting of discreet declarative rules which model a part of the business domain.

2.1.2 What is Drools?

JBoss Rules, or as it is more commonly known, Drools, is the leading opensource rules engine written in Java. In this paper when we use the name "Drool" we are referring to the "Drools Expert" which is the rule engine module of the Drools Suite. Drools started in 2001, but rose to prominence with it's 2005 2.0 release. It is an advanced inference engine using an enhanced version of the Rete algorithm, called ReteOO[12], adapted to an object-oriented interface specifically for Java. Designed to accept pluggable language implementations, it can also work with Python and .Net. It is considered one of the most developed and supported rules platforms.

For rules to be executed there are 4 major components as demonstrated in figure 2.1. The production memory contains the rules. This will not change during an analysis session. The rules are the focus of this thesis and therefore we will delve into much more detail later on these.

In Forgy's[2] overview of a rete algorithm, the following steps occur.

1. Match : Evaluate the LHSs of the productions to determine which are satisfied given the current contents of working memory
2. Conflict resolution : Select one production with a satisfied LHS; if no productions have satisfied LHSs, halt the interpreter

3. Act : Perform the actions in the RHS of the selected production
4. Re-evaluate : Go To 1

Figure 2.2 show more detail of how these components interact within Drools to infer a conclusion. First a fact or facts are asserted in the working memory. The working memory contains the current state of the facts. This triggers the inference engine. The pattern matcher, using the aforementioned ReteOO algorithm will determine examine the working memory and a representation of the rules from the production memory to determine which rules are true. Matching rules will be placed on the agenda. It can be the case that many rules are concurrently true for the same fact assertion. These rules are in conflict. A conflict resolution strategy will decide which rule will fire in which order from the agenda. The first rule on the agenda will fire. If the rule modifies, retracts or asserts a fact, then the inference loop begins again. If a rule specifies to halt or there are no matching rules left on the agenda, we have inferred our conclusion.

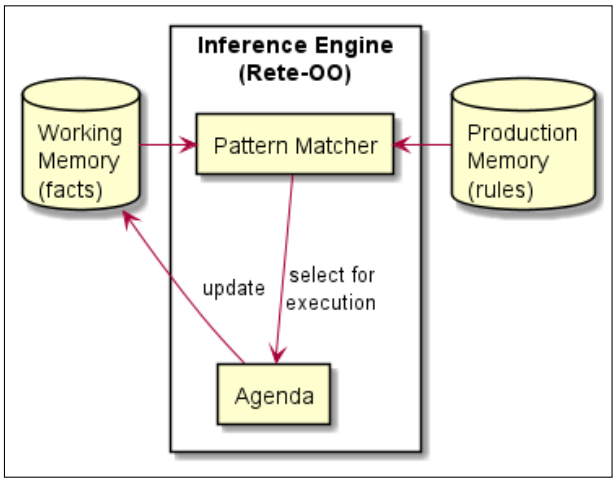

FIGURE 2.1: Drools components.

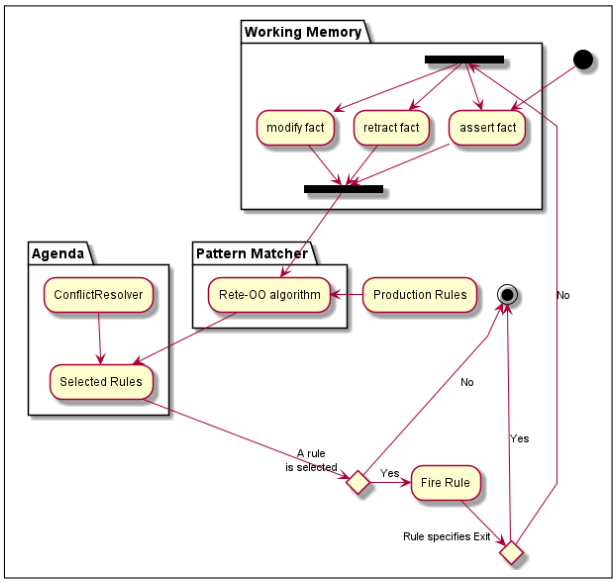

FIGURE 2.2: Drools Inference Loop.

The component we will be focussing on in this paper is the rules. Rules are stored in a rules file, a text file, typically with a drl extension. During execution the rules do not

change and are stored in production memory. For the sake of this paper we will skip past package, import, global, declare, function and query, which are also stored in the rule file. We will examine the anatomy of a rule.

A rule is made of 3 parts: attributes; conditions; and consequences. Attributes are an optional hints to the inference engine as to how the rule should be examined. The conditional, when, or left hand side (LHS) of the rule statement is a block of conditions that have to in aggregate return true for the asserted fact in order to be considered to be placed on the agenda. The actions, consequences, then, or Right hand side (RHS) of the rule statement contains actions to be executed, should the rule be filtered

The LHS is a predicate statement, made up of a number of patterns. variables can be bound to facts that match these patterns for use later in the LHS or for updating the working memory on the RHS. the patterns are used to evaluate against the working memory. The pattern match against the existence of facts. Patterns can also match against conditions of the properties of facts. Connectives such as not, and, and or can be applied to the patterns. The patterns apply to individual Facts rather than the group, thus can be seen as first order predicates.

There are some more advanced features in the LHS, but for this paper, these are the features we will be looking at.

Whilst the RHS can contain arbitrary code to be executed when a rule is fired, it's main purpose is to adjust the state of truth in the working memory. One can insert, modify, and retract facts in the working memory. modifying and retracting facts, must be done on fact variable references that have been created in the LHS. One can explicitly terminate the inference loop, with a halt command.

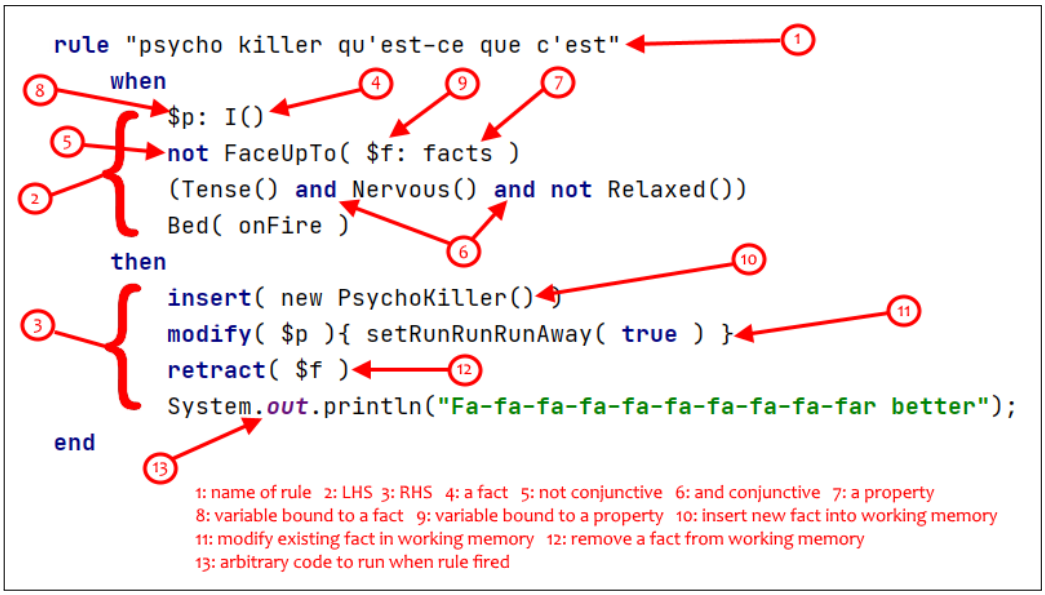

FIGURE 2.3: Drools Rule Breakdown.

An explanatory example

An example of a drl file can be seen in listing 2.1. This has been extracted from the Drools sample code.

```
1  package org.drools.examples.honestpolitician
2
3  import org.drools.examples.honestpolitician.Politician;
4  import org.drools.examples.honest politician.Hope;
5
6  rule ''We have an honest Politician''
7      salience 10
8      when
9          exists( Politician( honest == true ) )
10     then
11         insertLogical( new Hope() );
12 end
13
14 rule ''Hope Lives''
15     salience 10
16     when
17         exists( Hope() )
18     then
19         System.out.println(''Hurrah!!! Democracy Lives'');
20 end
21
22 rule ''Hope is Dead''
23     when
24         not( Hope() )
25     then
26         System.out.println( ''We are all Doomed!!! Democracy is Dead'' );
27 end
28
29 rule ''Corrupt the Honest''
30     when
31         $p : Politician( honest == true )
32         exists( Hope() )
33     then
34         System.out.println( ''I'm an evil corporation and I have corrupted '' + $p.getName() );
35         modify( $p ) {
36             setHonest( false )
37         }
38 end
```

LISTING 2.1: Example Drools file.

Listing 2.1 gives the Drools engine instructions on what actions to take when something changes in the working memory. What this toy example does is reacts to when an honest politician is added to the working memory, prints a message celebrating the existence of said politician, corrupts her, gloats in a message and then prints a message of despair. The code in listing 2.1 does the following:

1. on line 1 the package statement identifies the rule file
2. on lines 3 and 4 the import statements describes which facts can be used
3. the "We have an honest Politician" rule on line 6 does the following:
   (a) using salience on line 7 it sets that this rule is to be run before rules with a lower salience
   (b) on line 10 it checks the working memory for Politician facts with the honest property equal to true
   (c) on line 12, if found then Hope facts will be inserted into the working memory
4. the "Hope Lives" rule on line 15 does the following:
   (a) line 18 check if any Hope facts exist

   (b) on line 20, if found, it prints a message
5. the “Hope is Dead” rule on line 23 does the following:
   (a) checks if no Hope facts exist on line 25
   (b) if none are found, on line 27, it prints a message
6. the “Corrupt the Honest” rule on line 30 does the following:
   (a) line 32 checks for any Politician facts with the honest property equal to true, and sets them to the variable $p
   (b) line 33 checks if any Hope facts exist
   (c) if both hope and politicians are found on line 35 it prints a message including the $p variables name
   (d) on line 36 to 38 it modifies the fact in working memory represented by $p to change it’s honest property

2.2 Projectional Editing

2.2.1 What is projectional editing?

Traditionally programmers write code with text editors, or integrated development environments (IDE), which adjust the concrete syntax and allows a parser to create the abstract syntax tree. A projectional editor, Inverts this relationship, as a developer edits the abstract syntax tree and allows the IDE to project the concrete syntax.

parser based editing

In a traditional, parser-based, development workflow, a program is defined using text and can be edited with a text editor. Because it is text based then the notation of the language is limited to text. A grammar is a definition of the formal syntactical rules, or concrete syntax, of a programming language. The lexer and parser are derived from the grammar. The text is passed into a text buffer where first a lexer will turn the text into tokens. A parser will validates that these tokens, the words of the language, are syntactically correct. If the tokens are not rejected then the parser will construct first a parse, or concrete syntax, tree and from there, an abstract syntax tree (AST).

An AST is a tree structure that represents the semantic meaning of the source code, stripped of all the syntactic details. The parser will do some name resolution to take care that references within the source code are represented in the tree. This turns the tree into a graph.

Compilers use the AST to do subsequent processing, such as linking, transformation, analysis, type checking, etc. Modern IDEs, in the background, also parse the code it is displaying to create an AST in order to offer relevant coding assistance. This assistance is appreciated, because without IDE help learning the concrete syntax of large languages is error prone and exploratory programming is laborious if one has to wait until compilation to discover mistakes.

projectional definition

In the projectional editing paradigm the program is represented by a semantic model that can only be read and edited with projectional editing tools. A projectional editor does not parse any text. In its place, a developer reads and edits a representation of the AST through a projected notation. Her editing gestures immediately and directly manipulate the AST within predefined and fixed layouts.

The principle of projectional editing is familiar to those that use visual programming, like Scratch or Blockly, or graphical modelling tools, such as MetaEdit+. These tools do not parse pixels to get to their AST. They project the underlying models/programs in a view and which they store as the model/AST and not as a plain text equivalent in a traditional programming language.

Projectional editing is the generalization of this idea, with the ability to render multiple representation of the program with a wide range of notation styles.

The projection may sometimes seem like a text editor, however this is just acrobatics by the language engineer designing an editor that makes a developer feel more comfortable. The text is just another type of projection of the AST. It also may be any other notation that can represent the semantic meaning of the code, such as formulas, graphs, or images. Projections are not just the notation, but also how the user interacts with the projection. In this sense the definition of the projections and the IDE/UI overlap.

2.2.2 What is it not[TODO: write this section]

UML MDE MBSE

Low-code software development

Most confusing of all Projectional Editing the of projecting an editor from an AST, should not be confused with Projectional Editing the methodology of Product line differentiation in code bases. The reason we call this confusing is that as well as the name being the same, one of the leading products for this product line technique is called PEoPL, developed in MPS. This product is a projectional Editor (the paradigm) for product lines projectional editing (the methodology).

How projectional editing works

As shown in figure 2.4, a projectional editor has a model or an AST. It renders a presentation of the model as a projection. The developer performs actions on the projection. every user editing action is directly mapped on to a change in the AST.

To perform the above two things have to be defined by language engineers: The Meta-Model and the editor.

The meta-model, analogous to the abstract syntax, describes the node concepts and connection that can be used to build the, hierarchical structure that is the AST. This hierarchy can have references to nodes in other branches, so, although named a tree, it is

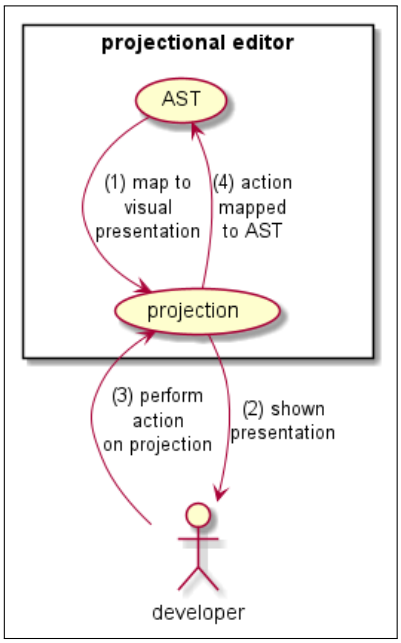

FIGURE 2.4: Projectional editing loop. TODO: comparison with Parsing

actually a graph. The AST will be stored independently of the concrete syntax. The tree is often stored with a database, XML or a proprietary file format.

Rules of the meta-model can further be described through behaviors such as type systems or scoping rules.

Projectional editors avoid the grammars and parsers that serve as the definition of the concrete and abstract syntax in a traditional text based language. Instead of transforming the concrete to the abstract with parsing, the abstract is transformed to the concrete via a projection engine that uses projection rules. Editors are a combination of the projection rules and the gestures or actions that will create change request to the AST. They are analogous to the concrete syntax.

One of the actions can be typing text, however, every string is recognized as it is entered, so there is no tokenizing and the text is being entered into the templates defined in the editor. The resulting changes are displayed to the developer in a newly derived projection of the underlying AST.

The projection uses graphical elements to represent the representation. Although often appearing textual, each of the text elements are references to nodes in the AST.

Developers can only interact with the editor via the rigidly controlled code completion menus or gestures and actions.

The AST is directly built from each interaction she has with the editor. Nodes are creates as instances of the concepts defined in the meta-model. Each node has it's own unique id and points to it's defining concept. It is unambiguous. References are first class and defined by the id rather than resolved by name, as in parser based languages. Disambiguation happens at time of input, as the developer choses from limited legal inputs.

The separation of the abstract and concrete allows the language engineer to implement multiple projections of the same model, using different notations, each node of the

AST taking having the design she envisions. The pattern used for projection is similar to MVC, so multiple views of the program can be visible and updateable at the same time.

Graphical modelling tools, for example for UML modelling, are specialized implementations of projectional editing. UML diagrams are not stored as pictures and whose pixels are parsed to create an AST. Instead the model is stored, often with extra information about visual layout, and the image of the UML is projected to the modeller to edit. Projectional editing generalizes this approach to projecting any notation defined by the language engineer.

2.2.3 Examples of projectional editing

Table 2.2 gives an incomplete and inconsistent history of projectional languages.

Language	Notes
MPS	inspired by a call to action for Language orientated program
	on a mission to build a product to fulfil that ideal. Meta Pro
	used to create the languages mbeddr, PEoPL, and Realaxy. H
Incremental Programming Environment[14]	A syntax-directed language independent editor from 1980.
Intentional Domain Workbench	Inspired by Charles Simonyi's 1995 essay "The Death of Con
	the IDW was the product of the company Simonyi founded
	In 2017 Microsoft, as a part of an "acquihire" bought Intenti
GANDALF[16]	Taking over from IPE in 1980 at Carnegie Mellon
Synthesizer Generator	
Whole Platform	
Más	
Onion	
Scratch	
Blockly	
Ardublockly	
Kogi	
https://snap.berkeley.edu/	
Prune	
Eco	
Lamdu	
Blueprints (Unreal Engine)	
Interlisp-D	
deuce	
Enso	
Cedalion	
Gentleman	

TABLE 2.2: An incomplete list of projectional languages

PEoPL

At the same time, projectional language workbenches like MPS [57] and Intentional [47]

Second, Behringer, Palz, and Berger (2017) present Projectional Editing of Product Lines (PEoPL), a DSL that enables multiple projections for variability mechanisms.

Such editors have existed since the 1980s and gained widespread attention with the Intentional Programming paradigm, which used projectional editing at its core.

Projectional editing, also known as structured editing or syntax-directed editing, is not a new idea; early references go back to the 1980s and include the Incremental Programming Environment [32], GANDALF [35], and the Synthesizer Generator [39]. Work on projectional editors continues today: Intentional Programming [44, 18, 45, 14] is its most well-known incarnation. Other contemporary tools [20] are the Whole Platform [9], Más [3], Onion, and MPS [4]

Projectional Editors from the 1980s. GANDALF [35] and the Incremental Programming Environment (IPE) [32] do not attempt to make editing textual notations efficient; for example, they lack support for linear editing of tree-structured expressions. The Synthesizer Generator [39] avoids the use of projectional editing at the fine-grained expression level, where textual input and parsing is used. While this may improve editing efficiency, it risks the advantages of projectional editing, because language composition at the expression level is limited. Another work that implements and uses a DSL within the Synthesizer Generator [37] concludes: "Program editing will be considerably slower than normal keyboard entry, although actual time spent programming non-trivial programs should be reduced due to reduced error rates."

The Intentional Domain Workbench (IDW) is the most recent implementation of the Intentional Programming paradigm [44, 18], supporting diverse notations [45, 14]. Since it is a commercial, closed-source project without widespread adoption yet, we cannot easily study it or survey its users.

All contemporary projectional editors are part of language workbenches

An early example of a projectional editor is the Incremental Programming Environment (IPE) [16]. It supports the definition of several notations for a language as well as partial projections, where parts of the AST are not shown. However, IPE did not address editor usability; to enter 2+3, users first have to enter the + and then fill in the two arguments. Another early example is GANDALF [17]; the report in [20] states that the authors experienced similar usability problems as IPE: "Program editing will be considerably slower than normal keyboard entry, although actual time spent programming non-trivial programs should be reduced due to reduced error rates." The Intentional Programming project [9, 22] has gained widespread visibility and has popularized projectional editing; the Intentional Domain Workbench (IDW) is the contemporary implementation of the approach. IDW supports diverse notations [7, 23].

Scratch [15] is an environment for learning programming. It uses a projectional editor, but does not focus on textual editing; it relies mostly on nested blocks/boxes. So does GP [18]. Textual notations, and thus grammar cells, are not relevant. Prune [2] is a projectional editor developed at Facebook. The goal is explicitly to not feel like a text editor; the hypothesis is that tree-oriented editing operations are more efficient than those known from text editors. While this is an interesting hypothesis, our considerable experience with using projectional editing in real projects has convinced us that this approach is not feasible; hence the work described in this paper.

The Synthesizer Generator [21] is a projectional editor which, at the fine-grained expression level, uses textual input and (regular, textual) parsing. While this improves usability, it destroys many of the advantages of projectional editing in the first place, because language composition and the use of non-textual notations at the expression level is limited.

Eco [10] relies on language boxes, explicitly delineated boundaries between different languages used in a single program (e.g., the user could define a box with Ctrl-Space). Each language box may use parsing or projection. This way, textual notations can be edited naturally, solving the usability issues associated with editing text in a projectional editor.

*** gothere Lamdu [5], a functional, projectional language (no paper)

Dataflow visual programming languages, such as Blueprints in the Unreal Engine [2], are often domain-specific.

Early syntax-directed source code editors included Interlisp-D (for Lisp's limited syntax) and Emily[1] (for PL/I's rich syntax).

deuce: lightweight structured editing in sketch-n-sketch

Blockly: https://developers.google.com/blockly

mage? r Jupyter notebooks

citrus visual macro system in Racket

An early example of a ProjE is the Incremental Programming Environment (IPE) [4]. Another early example is GANDALF [5], which generates a ProjE from a language specification.

The Synthesizer Generator [7] is also a ProjE. However, at the fine-grained expression level, textual input and parsing is used. While this improves usability, it destroys many of the advantages of projectional editing in the first place, because language composition at the expression level is limited. In fact, extension of expressions is particularly important to tightly integrate an embedded language with its host language [8].

The Intentional Programming [2,3] project has gained widespread visibility and has popularized projectional editing; the Intentional Domain Workbench (IDW) is the contemporary implementation of the approach. IDW supports diverse notations [9,10].

Language boxes [11] rely on explicitly delineating the boundaries between different languages used in a single program (e.g., the user could change the box with Ctrl-Space). Each language box may use parsing or projection.

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Cedalion's

What advantages does projectional editing bring?

Projectional editing gives advantages both to the language engineer and the program developers. There is a lot of crossover and repetition between papers written on the subject

of projectional editing as to the advantages it brings. To that end, what follows is a synthesis of a number of papers as to the advantages given. Rather than attributing advantages in line to their citations, a helpful reference of papers which proclaim such advantages can be found in table 2.3.

Advantage	#	Paper(s)
Exploratory programming	5	[17–21]
Correctness-by-construction	7	[17, 22–26]
Rich notation	22	[15, 17, 19, 20, 25–42]
Mixed notation	8	[18–20, 28–32]
Multiple views	9	[17, 19, 26, 28, 29, 31, 33, 37]
Language composition	23	[15, 19, 20, 22, 23, 25, 26, 28–32, 37, 38, 41–49]
IDE functionality	4	[17, 29, 31]
Language evolution	1	[50]
Ancillary data	5	[19, 29, 42, 48, 49]

TABLE 2.3: Papers describing advantages.

Exploratory programming As with their progenitors, syntax-directed editors, modern projectional editors help guide a developer unfamiliar with a language. The defined editors with rigid syntax and pre-defined layout mean that only specific cells within the editor can be edited. This template style means the she does not have to worry about significance of spacing or indentation. Minutiae of syntactic adornments, such as statement ending semi-colons or enclosing matched brackets, are also not interfering with her exploration of the language space.

When creating code the developer is only presented with legal options within the current context. As the projection is context aware, relevant actions or options can be suggested and irrelevant ones can be removed. Thus, it is easier for her to explore which options and actions the language allows her to choose. Intelligent code completion does not have to be limited to single nodes. Whole subtrees can be inserted allowing the developer to explore the larger structures of the language.

Correctness-by-construction A projectional editor, by controlling the interaction between the developer and the AST, prevents her from writing syntactically incorrect code. The whole class of syntactical errors are made impossible, with the developer relieved of having to think about special characters and layout. Typing and scoping errors are removed by only allowing validly typed and scoped options for the developer.

The developer is only able to select statements that are legal in the context of the location within the AST. Code does not have to be disambiguated, as this happens at time of entry by the developer. If there are multiple items that share the same presentation in the editor, the developer chooses the relevant item, resolving the ambiguity to what she means rather than what the parser thinks she means.

Rich notation The choice of projection is unconstrained by the restrictions of code that needs to be parsed from a textual source. This freedom opens up diverse otherwise difficult or impossible to parse notations. Examples include tabular, mathematical expressions and symbols, diagrams, trees, images, forms, prose, sub- and superscript. Any visual

form or shape that can be mapped to the AST can be used to represent the program in an editor.

With these notations one can better reflect the semantics of the program domain, which should aid comprehension. Mathematics has a rich history of use of notation. When writing a DSL for the Mathematics domain, the domain experts can interact with it in the centuries old language of their domain.

Of course the projections can also be projections of text. This is often the appropriate projection type if the developer interacting with the language's domain expertise is parser-based languages.

Mixed notation Because no parsing is required, the different forms of rich notation can be combined without the need to create a unifying parser. With all notations working on the same editor infrastructure mathematic symbols can be embedded within textual projections, within tables within graphical representations. As ambiguity is not an issue for the underlying AST, then mixing different notations becomes much easier.

Multiple views With the AST being the stored artefact rather than the notation, projectional editing allows the language engineer to define multiple views on the same model optimised for different tasks. Similar to how software architecture presents different views for different stakeholders interests, the same notational diversity can be achieve with specific editors targeted to experts in the various parts of the domain. A developer can switch between different projections of a node within a larger projection, to find the one that best suits their current task.

Because the architecture of a projectional editor follows the principles of model view controller, it is possible to have multiple simultaneous views of the model. This allows the developer to update a projection that is optimised for writing and immediately see its effect in a projection optimised for understanding.

Language composition Parser-based languages can support some modularization and composition, but a projectional editor allows easy and extensive modular language extension and composition. This is a result of the nodes of an AST being disambiguated at entry rather than through a parser. If two items with the same syntax are available at the same place, then the user will choose the one that they require, and therefore the node has an explicitly chosen meaning.

The composition of independently developed languages does not suffer from the syntactic or keyword clashes they would in two grammar defined languages. Because of the lack of ambiguity, every node referencing the concept that defines it, these languages, when put together, will not have structural or syntactic issues.

Composition can involve extending an existing language or embedding other languages in a host language without modifying the definition of said language. The ease of composition and extensions leads to the advantage of being able to build larger languages out of smaller modules.

IDE functionality Developers in mature languages are used to the functionality of mature IDEs. These functionalities include syntax highlighting, intelligent code completion or suggestion, and static analysis for errors and validation. As projectional languages store the AST rather than the the concrete syntax, they require an IDE to edit. Because of this, when a language engineer designs the language she also has to design the IDE.

Because the projection is based on the AST it always knows it's context. When the editor already knows the meaning of the node it is representing, then syntax highlighting is simple. From knowing it's context, it makes it much simpler to suggest intelligent code completions.

Always having a complete AST makes it much easier to validate scope, typing and other hard to implement code validators.

Language evolution Parsing complicates the evolution of languages, for example, adding a new reserved word is difficult without breaking existing code. Extending a language with new capabilities and syntax in projectional editing is simple. If the change is syntactic then the language engineer has to update an editor. If there is a semantic change then the language engineer can write a migration in the language, to transform a node of one concept to a different type, and the developer would have to run that migration on their code.

Ancillary data Data can be added to nodes that can augment the AST. This has shown to be useful for documentation, requirements traceability and product line feature dependencies.

What are the disadvantages of projectional editing?

Whilst there are fewer papers proclaiming the disadvantages of projectional editing, we repeated the approach of the previous section. Thus, we have synthesised the disadvantages from papers in the following sections and listed citations for these ideas in the table 2.4

We do not consider that the dearth of disadvantages discussed as evidence of projectional editing's superiority. We consider that those who do not find projectional editing useful do not write papers about it.

Disadvantage	#	Paper(s)
Low adoption	4	[26, 30, 39, 41]
Unnatural user experience	11	[20, 25, 26, 28, 29, 31, 37, 39, 41, 47, 50]
Ambiguous syntax	1	[32]
Inflexibility	2	[20, 28]
lack of integration with text ecosystem	5	[20, 28, 39, 47]
Learning curve	5	[20, 29, 30, 38, 47, 51]
Vendor lockin	2	[29, 31, 52]

TABLE 2.4: Papers describing projectional editing disadvantages.

Lack of adoption The ideas that proceeded projectional editing - structured editor or syntax-directed editor - has been around since the early 1970's yet has failed to be adopted widely. This argument is a bit of a tautological one, as the low adoption is perhaps an outcome of the other disadvantages of projectional editing. However, low adoption can lead to a vicious circle where lack of adoption prevents further adoption.

Inconvenient or unnatural editing Early attempts at projectional editing presented an inconvenient and unnatural user experience when coding. These usability challenges, exemplified by the tedious manner of entering code as per the order of the tree, compares badly to parser based languages. A traditional text based language can be entered the way it looks, by typing the characters one after another,

This bad reputation continues, despite massive improvements in projectional editors. Whilst there is no debate that projectional editing feels different, it is questioned as to whether this inconvenience is an intrinsic property or a result of developers, through year of experience, being used to text based programming.

Modern projectional editors, when using a textual syntax face an "uncanny valley" issue. Whilst trying to simulate a text editor, the developers start to expect all of the functionality of the text based IDEs. This is a particular weak spot, especially with regards to granularity and restrictions of cursor movement, insertion, deletion, selection, copy and pasting, and other interacting with text

Ambiguous syntax One of the selling points of projectional editing, especially when it comes to language composition, is that there can be no ambiguous syntax. Whilst this may be true for the AST, it is not so for the developer as they read this code on the screen. If one combined Drools and Basic rather than Java, the developer may become confused as to which language the "Then" keyword refers when she read it.

Inflexibility As a developer one has no flexibility in code layout, perhaps for enhanced readability. This is entirely in the hands of the language engineer when determining the projection rules.

Integration with the text based world Projectional editors do not store the definition of the program in the form of a plain text implementation in the concrete syntax. Instead the AST is stored and serialized in a format not meant to be human readable, such as XML.

This leads to an issue with integration with the infrastructure that has grown around text based programming languages. Two notable examples are text diffing, especially where branch merging is concerned and code sharing. The diffing issue can and has been solved within projectional editing tools. This is however difficult to integrate into the workflows of software development workflows that include multiple tools.

Textual source code can be be shared simply by email or websites, this is not the case with projectional code.

Learning curve For the language engineer, the necessity to develop an editor with a good user experience is much harder work than defining a grammar for a parsed language. The

learning curve for the language engineer is significant, as by default, she has to think also of the IDE development.

For the developer, the different style of editing takes some getting used to.

Vendor lock-in The nature of projectional editing is that what one edits is a projection of the AST and therefore an IDE is needed to do the projecting, as well as language definition. Organisations thinking of going the projectional route for their DSLs may fear being locked into a specific implementation of the concept. To be able to use previously developed languages would require using the same tool set. Changing to a different toolset for language design would require a significant re-skilling effort.

2.3 What is MPS?

Language workbenches (LWB) are a tool to help language engineers create languages, particularly domain specific languages (DSL). The term LWB was popularized in a 2005 article by Martin Fowler[53].

Meta Programming System (MPS) is an opensource LWB that assists in the creation of Projectional languages. It started in 2003 by JetBrains, and introduced to the world in Sergey Dmitriev's 2004 Paper "Language Orientated Programming: the Next Programming Paradigm"[13].

As discussed in section 2.2.1, When creating a projectional language one has to not only define the language but also how one interacts with it. MPS lets you define languages and solutions in which you can use your defined language, in conjunction with languages defined by others, to write programs.

The following is an overview of how MPS implements the ideal of a projectional language, as well as the structure of this section:

- Abstract syntax
  - Structure
  - Behaviors
  - Constraints
  - Type system
- Concrete syntax
  - Editors
  - Intentions
- Generators
  - Model-to-Model
  - Model-to-Text

MPS defines the different aspects of the language definitions with declarative DSLs, bundled together in what they call Aspects.

2.3.1 Abstract syntax: Structure

Structure is what determines the abstract syntax of a language. The most important item available in a Structure Aspect is the Concept. Instances of concepts are called nodes and it is with these that the programmers construct their programs, i.e. their Abstract Syntax Trees (AST).

In principle a concept is a contains three types of things:

1. properties: these primitives are integer, boolean, string, or enum items and could be seen as leaf values.
2. children: these are other concepts, or collections of them, and could be seen as sub trees.
3. references: these are relationships with other nodes in the AST. These turn the tree into a graph.

Concepts follow some object orientated (OO) traits, such as being able to subtype, being abstract, and implementing interfaces. At least one rootable concept needs to be defined in order to be able to create a program.

Other items available in the Structure Aspect are the Interface Concept, the Enumeration, the Constrained Data Type, and the Primitive Datatype. [1]

Thus, the structure aspect defined how the AST can be structured.

Figure 2.5 shows a concept with three children that implements two interfaces.

```
concept RuleStatement extends    BaseConcept
                      implements INamedConcept
                                 IFileLevelStatement

  instance can be root: false
  alias: rule
  short description: rule

  properties:
  << ... >>

  children:
  attributes : RuleAttributes[1]
  conditions : AbstractCondition[0..n]
  outcomes   : StatementList[1]

  references:
  << ... >>
```

FIGURE 2.5: concept example

[1] At time of writing we are unaware as to whether Data Type and Datatype are semantically different or if it is a style choice.

2.3.2 Abstract syntax: Behaviors

OO design usually bundles together data and methods that can act on that data. Concepts are analogous to the data part of this equation. Behavior fill the role of the methods in the OO analogy, defining the functionality that can be called on instantiated the nodes, as well as static methods which can be called on the Concept. These methods include a constructor for a node.

The methods have public, private, or protected visibility. If the Concept to which the behavior refers is abstract, the behavior itself can contain abstract Methods. This allows a sort of polymorphism, as if a method is declared as being virtual then it will be called polymorphically.

Figure 2.6 show a constructor being added to a concept to initialize its children. It has a method to allow other nodes to interrogate the condition of it having attributes.

```
concept behavior RuleAttributes {

  constructor {
    this.salience = new node<SalienceAttribute>();
    this.salience.salience = new node<IntegerConstant>();
    this.salience.salience:IntegerConstant.value = 0;
    this.noloop = new node<NoLoopAttribute>();
  }

  public boolean hasAttibutes() {
    return this.salience.visible || this.noloop.visible;
  }

}
```

FIGURE 2.6: behavior example

2.3.3 Abstract syntax: Constraints

The constraints aspect adds further structural constraints to concepts. These constraints are especially used to define scope. Other constraints including allowing if a node can be a child, a parent, or an ancestor of this node. the constraints aspect also allows preventing badly formed properties, children or references.

Figure 2.7 shows an example of a scope restraint that only allows local variables that are declared within the same rule or global variables declared in the same file.

2.3.4 Abstract syntax: Type system

The TypeSystem aspect and the constraints aspect together represent the static semantics of the language. This aspect is for the computation and evaluation of types of variables, expressions and statements.

Rules that are available to calculate and enforce the type system include inference, subtyping, comparison and substitute type rules.

```
concepts constraints RuleVariableRef {
  can be child <none>

  can be parent <none>

  can be ancestor <none>

  instance icon <none>

  <<property constraints>>

  link {target}
    referent set handler <none>
    scope (referenceNode, contextNode, containmentLink, position, linkTarget)->Scope {
      node<RuleStatement> rule = contextNode.ancestor<concept = RuleStatement, +>;

      nlist<RuleVariable> localVars = rule.descendants<concept = RuleVariable>;

      sequence<node<RuleVariable>> globalVars = rule.containingRoot.descendants<concept = GlobalStatement, +>;

      return ListScope.forNamedElements(localVars.concat(globalVars));
    }
    <no presentation (deprecated)>


  default scope <no default scope>
}
```

FIGURE 2.7: constraint example

Figure 2.8 shows an inference rule that is ensuring that the calculated type of the import statement matched the that of it's child called type.

```
inference rule typeof_ImportStatement {
  applicable for concept = ImportStatement as importStatement
  applicable always
  overrides false

  do {
    typeof(importStatement) :==: typeof(importStatement.type);
  }
}
```

FIGURE 2.8: typesystem example

2.3.5 Concrete syntax: Editors

Editors define the notation of the nodes. In effect it is the user interface of the language, how the AST is projected to the developer. An editor is a swing panel that renders a tree of editor cells. A concept can have multiple editors, thus offering multiple views on it.

The editor aspect is also where you can redefine what options will be presented to developers, through substitute menus. Transformations can be defined, so that when a certain option is input by the developer, the existing AST is transformed to match the meaning of the choice.

Behavior of interactions can be defined, such as what will happen to the AST when a particular key press or editor action occurs at a particular location.

Figure 2.9 shows a component with one projection for the concept shown in figure 2.5.

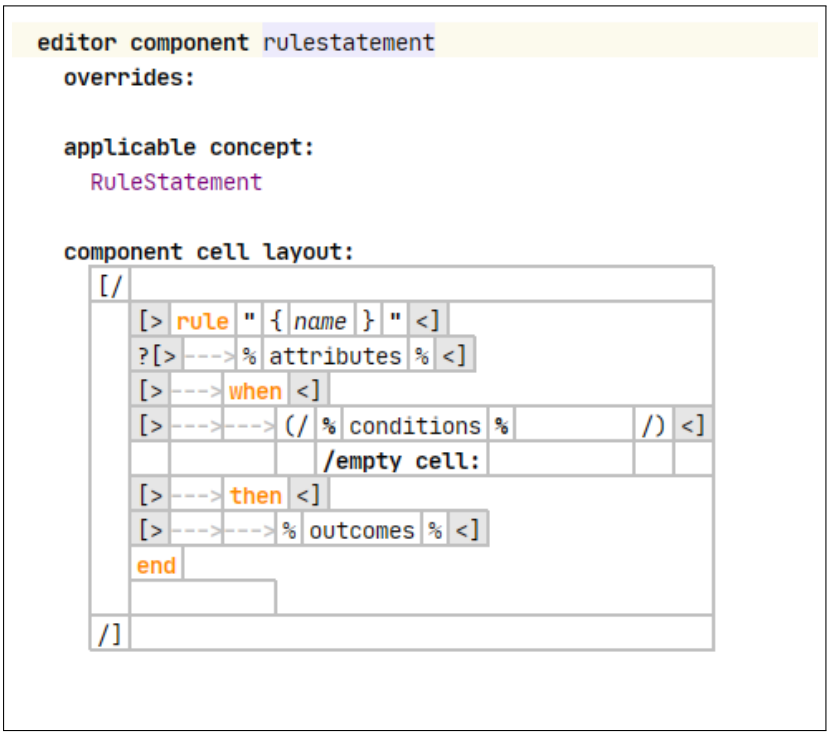


FIGURE 2.9: editor example

2.3.6 Concrete syntax: Intentions

In projectional editing it can be said that the IDE is a part of the concrete syntax. Intentions make context aware suggestions for automatic changes to the program to the developer.

Figure 2.10 shows an intention that allows the developer to add, remove or edit a property based on it's current value.

```
intention addSalienceRule for concept RuleStatement {
  error intention : false
  available in child nodes : true
  child filter :

  description(node, editorContext)->string {
    node.attributes.salience.visible ? "Remove Salience Attribute" : "Add Salience Attribute";
  }



  execute(node, editorContext)->void {
    if (node.attributes.salience.visible) {
      node.attributes.salience.visible = false;
    } else {
      node.attributes.salience.visible = true;
      node.attributes.salience.select[in: editorContext, cell: FIRST_EDITABLE];
    }
  }
}
```

FIGURE 2.10: intention example

2.3.7 Generators: Model-to-Text

Whilst designing a language is nice, it has to be able to do something, without doing so it has no semantic meaning. It is possible to create interpreters that can use the AST generated by MPS. However, the most common modality for MPS is to generate an output to be compiled and run by commonly known environments. The output stage of generation is called TextGen. It defined how a node will be turned into runnable code in plain text.

2.3.8 Generators: Model-to-Model

Whilst the base level languages will have text generation, most DSLs will perform model-to-model conversions. These are known as Generator Aspects. They transform code written in one language to another. A concept can have multiple generators, aimed at different base level languages, such as Java (using MPS BaseLanguage), C (using mbeddr) or XML.

Chapter 3

Methods

To answer the research questions from section 1.2, we formed three approaches. The question

3.1 Method: Systematic Review

To answer the first Research Question, "what is the current state of Projectional Editing?", we conducted a systematic literature review. Hereafter, we describe the method we undertook.

To carry out this review we followed Kitchenham's[54] advice on systematic review protocol validation, (see appendix A for the exact checklist we used).

3.1.1 Motivation

The motivation that preceded this research was a requirement to understand if projectional editing was an idea that was worth investigating. Through our background research we saw an interest in the precursors to projectional editing in the late 70's through to the mid 80's. This seemed to be abandoned until the mid 90's following Charles Simonyi's treaties on Intentional programming. This did not lead to a swell in academic research as his companies product, Intentional Domain Workbench was a closed commercial product. There seemed to be a burst of academic interest after the release of JetBrain's Open-Source Meta Programming System (MPS) in the late 2000's.

Is there a need for a study of this topic? We believe, at least in the microcosm of this master's project it is helpful to know whether we are researching in an area that is dying of vibrant.

For the wider community, there does not seem to be any systematic reviews specifically about projectional editing, let alone recently. This study is not extending any previous Systematic Review as, although there were literature surveys and mapping studies covering some adjacent fields, no SLRs were found. Thus we believe it may be useful for those in the language engineering research community to bring together all current research in the area of projectional editing in one place.

3.1.2 Research Question

This paper we only have one research question to synthesize the findings of scientific papers towards. This is "What is the current state of Projectional Editing?"

This question for us can be broke down into:

- **Sub Question 1** "Is there current research in the area of projectional editing?"
- **Sub Question 2** "What tools are currently being used for research?"
- **Sub Question 3** "What is the sentiment in papers currently discussing projectional editing?"

3.1.3 Search Strategy

The search process is automated as SLRs require a high level of completeness, which cannot be effectively achieved manually. Our first major decision was whether to engage in creating a quasi-gold standard as advised by Zhang[55]. Zhang noted that the ad-hoc nature of search strategies in SLRs has limitations. We executed a preliminary ad-hoc search to try and ascertain the extent of the research space. Upon satisfying ourselves that it was small enough, we rejected the Quasi-Gold standard as overkill for our requirements.

The search terms we landed on were as follows:

```
"PROJECTIONAL EDITING"

OR

"PROJECTIONAL EDITOR"
```

This is to be adjusted to fit the query syntax of the various search engines.

As most Research Search engines offer the option of date ranges, and to save the effort of excluding later we also used the date range to eliminate unnecessary paper at the automated search stage. Our research question we are specifically looking at the current state of projectional editing. A design decision of many research search engines is that date ranges can often only be defined in whole years. When designing our search strategy, it was near the beginning of 2021, and thus we feared that this would be too small a search space, thus we set our date range to be from the beginning of 2020 to present. For the sake of reproducibility, it is advised to remove any papers after 31st July 2021.

The Search Engines used are shown in table 3.1.

ACM digital library	Google Scholar
BASE	CORE
IEEE Xplore	ISI Web of Science
Microsoft Academic	Science.gov
Wiley InterScience	SCOPUS
Semantic Scholar	SpringerLink

TABLE 3.1: Search Engines Used

Once we have filtered the automated search through the criteria of the selection stage, we will use that as our starting set for snowballing. Our filtering will be done before the quality of the papers has been assessed, as we feel that excluding papers on quality of primary study issues may artificially limit the network of potential papers. Our snowballing procedure shall follow the advice of Wohin[56]. This is the idea of using the reference lists from our start set and applying the same selection criteria to these.

Where possible we will get the forward snowballing papers from the "cited by" functionality of Google Scholar. Because of the range of the search being to present, all papers that cite the target paper will fall within our criteria. For backward snowballing we will manually filter the bibliography section of the selected papers, selecting any paper published in 2020 or 2021

After gathering all the papers from the forward and backward snowballing we will again apply the selection criteria. This process will iterate recursively until no new papers are found. All of the papers not excluded in each iteration will be the basis for the quality of primary studies filtering stage.

After the final iteration, as a final step the selected papers will have a deeper scan. This is to verify our initial scan that the papers met our inclusion criteria, before moving on to the quality assessment.

3.1.4 Study Selection

The inclusion criteria are:

- Studies are about or mention projectional editing or one of it's synonyms
- It is published in during the period 20202021

The exclusion criteria are:

- Books and grey literature
- not English
- no full text available
- papers with serious issues with grammar or vocabulary
- not a previously selected paper

- not a paper about a previously reported on study

If multiple papers look at the same study with different approaches, then the data will be aggregated in the synthesis stage.

As a lone researcher, we must be aware of bias in positively including relevant papers and excluding irrelevant papers. We will follow Kitchenham's suggestions to overcome such bias:

- Test-retest
  - We will assess the papers once (on title abstract and keywords) against the inclusion and exclusion criteria.
  - Save all the suggested results
  - Assess the papers again three days later in a different order to the first
- If there are disagreements, we will use Cohen's Kappa agreement statistic[57] to see if the process needs to be refined.

If our searches appear to be too large for a lone researcher, we will turn to text mining. We will be cautious to use this. O'Mara-Eves et al.'s systematic review of text mining in systematic reviews[58], recommends that this can be used for prioritization, but finds that for exclusion screening, although promising, it is not yet proven.

An SLR is interested in studies rather than papers. There is a many-to-many relation between papers and studies. We will review the selected papers to note when this has happened in our results to make sure studies do not get over or undercounted.

3.1.5 Quality of Primary Studies

To discover explanatory reasons for why there may be differences in study results, and to weigh how valuable specific studies are, we will assess the quality of the selected studies.

To try and avoid a Results Section bias we will be operating a results-blind quality assessment. Study quality will be based on the methods section of the papers only. This bias is threatened because results are summarized in the abstract. The study quality will not be measured until after the selection process is complete, though it will, in part be carried out before the selection re-test. list of papers will be randomly sorted before assessing for quality.

For EBM studies there are some well-known hierarchies of evidence for study quality thresholds such as the CRD Hierarchy of Evidence[59]. Kitchenham in, Procedures for Performing Systematic Reviews[60], suggests the hierarchy shown in table 3.2

Rank	Description
1	Evidence obtained from at least one properly designed randomized controlled trial
2	Evidence obtained from well-designed pseudo-randomized controlled trials (i.e. non-random allocation to treatment)
3-1	Evidence obtained from comparative studies with concurrent controls and allocation not randomized, cohort studies, case-control studies or interrupted time series with a control group
3-2	Evidence obtained from comparative studies with historical control, two or more single-arm studies, or interrupted time series without a parallel control group
4-1	Evidence obtained from a randomized experiment performed in an artificial setting
4-2	Evidence obtained from case series, either post-test or pre-test/post-test
4-3	Evidence obtained from a quasi-random experiment performed in an artificial setting
5	Evidence obtained from expert opinion based on theory or consensus

TABLE 3.2: Study design hierarchy for Software Engineering

These different types of study have different quality assessment criteria. As the nature of our research questions is not likely to attract randomized or pseudo-randomized controlled trials or experiments, our quality assessment checklists are created with comparative studies and case series in mind. To assess the strength of each primary study we used the checklists shown in appendix C. The checklists were based on a subset of the questions suggested in Keele's guidelines on SLRs[61], which in turn extracted questions from previous mostly medical systematic reviews. Where necessary the selected questions were modified for software engineering.

These checklists are addressed toward general research. In Software Engineering many studies that fall under what Gregor[62], in "A Taxonomy of Theory Types in Information Systems Research" calls "Type V: Theory for Design and Action". The checklists do not address this type of research well. On investigation into how others SLRs conduct quality assessment we did not find a solution to this issue. Therefore we will continue with the checklists as in the appendix, using the checklists for Case Study for Type V research papers. We will take this into account before dismissing results of this type on basis of their quality score.

As this study will be carried out by a lone researcher, there is no need to have a process for disagreements. To check on the bias, several papers will be randomly selected and assessed using the checklist by the academic and the daily supervisors. Should there be a high disagreement the design of the checklist will be revisited.

The quality checklist is trying to weed out the biases of selection, performance, detection, and exclusion, as well as other threats to the validity of the studies under test. Validity issues can occur during the design, operation, analysis, or conclusion of an empirical study.

3.1.6 Data Extraction

No data extraction will be necessary for the first sub-question, "Is there current research in the area of projectional editing?". The fact of the existence of papers that have been verified to be primary studies either into projectional editing theory or practical use of it will be enough to answer the question.

For the question of "What tools are currently being used for research?", we shall note each tool discussed specifically with regards to the study being carried out.

Finally, for the sentiment we shall pass each paragraph of the introduction, the discussion and the conclusion through a sentiment analyser and, if the paragraph is pertinent to projectional editing, we will not it's sentiment score. The sentiment analysis tool we shall use is Microsoft Azure Cognitive Services Text Analytics. The code to carry out this task is shown in listing 3.1

```
from azure.core.credentials import AzureKeyCredential
from azure.ai.textanalytics import TextAnalyticsClient

endpoint = "REPLACE_WITH_CORRECT_ENDPOINT"
key = "REPLACE_WITH_CORRECT_KEY"

text_analytics_client = TextAnalyticsClient(endpoint=endpoint, credential=
    AzureKeyCredential(key))

inputfiles = [[ARRAY_OF_FILES_TO_BE_ANALYSED]]

with open('/content/sample_data/sentiment/output_all.txt','a') as outf:
  for sections in inputfiles:
    for section in sections:
      print("Section: {}".format(section),file=outf)
      f = open('/content/sample_data/sentiment/'+section)
      content = f.readlines()
      # for brevity an optimization to deal with 10 document limit is removed
      if len(content) != 0:
        result = text_analytics_client.analyze_sentiment(content,
            show_opinion_mining=True)
        docs = [doc for doc in result if not doc.is_error]
        for idx, doc in enumerate(docs):
          print("sentiment: {}".format(doc.sentiment),file=outf)
          print("Document text: {}".format(content[idx]),file=outf)
```

LISTING 3.1: Text Analytics code.

#	Data Type	Description	RQ
1	Study ID	Unique identifier for the study	
2	Title of Study	The paper name	
3	Year of Publication	Will be either 2020 or 2021	
4	Author(s) Names	Including affiliation	
5	Source of Study	Name Of Online Database/ Digital Library	
6	Type of Study	Publication/Conference/Workshop/Symposium	
7	Name of Venue	Journal/Conference in which study has been published	
8	Tools in Study	A list of the tools used	RQ 1.2
9	Sentiment	The sentiment scores from appropriate paragraphs	RQ 1.3

TABLE 3.3: Data extraction form.

3.1.7 Data aggregation and synthesis

As explained by Kitchenham[63], in software engineering, primary studies will tend to be too heterogeneous for any statistical analysis. Synthesizing outcomes from multiple methods will be difficult. Thus our synthesis will take a narrative approach.

Narrative synthesis is telling a story of the who, how, and why of the success or otherwise of the research. For ADR research, focus will be on what will help or hinder the adoption of the implementations. It will also examine how reliable the results are and relationships between the studies.

3.2 Method: Action Research - Drools in MPS

Even though Drools is a relatively small DSL, we did not feel the need to implement all of the functionality to answer our questions.

3.2.1 Really Simple Rules Language

As we were new to DSL design and MPS, we First would create a very simple approximation of the Drools language with which to create our first projections. We called this language "Really Simple Rules" (RSR).

File RSR, Like Drools itself, has a File as it's root node. The file only contains Facts and Rules.

Fact and FactProperty In Drools a fact represents a Java Bean with its subsequent properties which can also be types with their own properties. In RSR we limited properties to only allow boolean values. This decision was based on the fact selection is a predicate and thus can only return a boolean. By only having booleans we also limit the operations on the property.

Rule For the Rules Concept, we decided to only simulate the Left Hand Side, or "When" conditions, of a Drools Rule. We believed this would be enough to provide us with interesting projections, and did not want to over complicate this first approach. An RSR Rule consists of a collection of conditions. Should all those conditions return true then the rule is selected.

Condition A condition operates on one or more FactSelectors. There are four condition type Exists, Not, And, and Or. Exists and Not are unary conditions and evaluate one FactSelector. And and Or evaluate two Fact Selectors.

FactSelector a FactSelector consists of a reference to a Fact and a collection of Predicates. If the Fact exists and all the predicates evaluate to true then the fact selector evaluates to true.

Predicate the predicate is an operation on a fact property, to which the concept has a reference. As the fact property represents a boolean value, then the only predicate operations are "Is" and "Not".

Figure 3.1 shows the Concept hierarch for this very simple implementation.

This design was then realised in MPS. As the aim is to attempt different projections we did not initially optimise for editing. The structure is as show in figure 3.2 and the editors including those shown in figure 3.3.

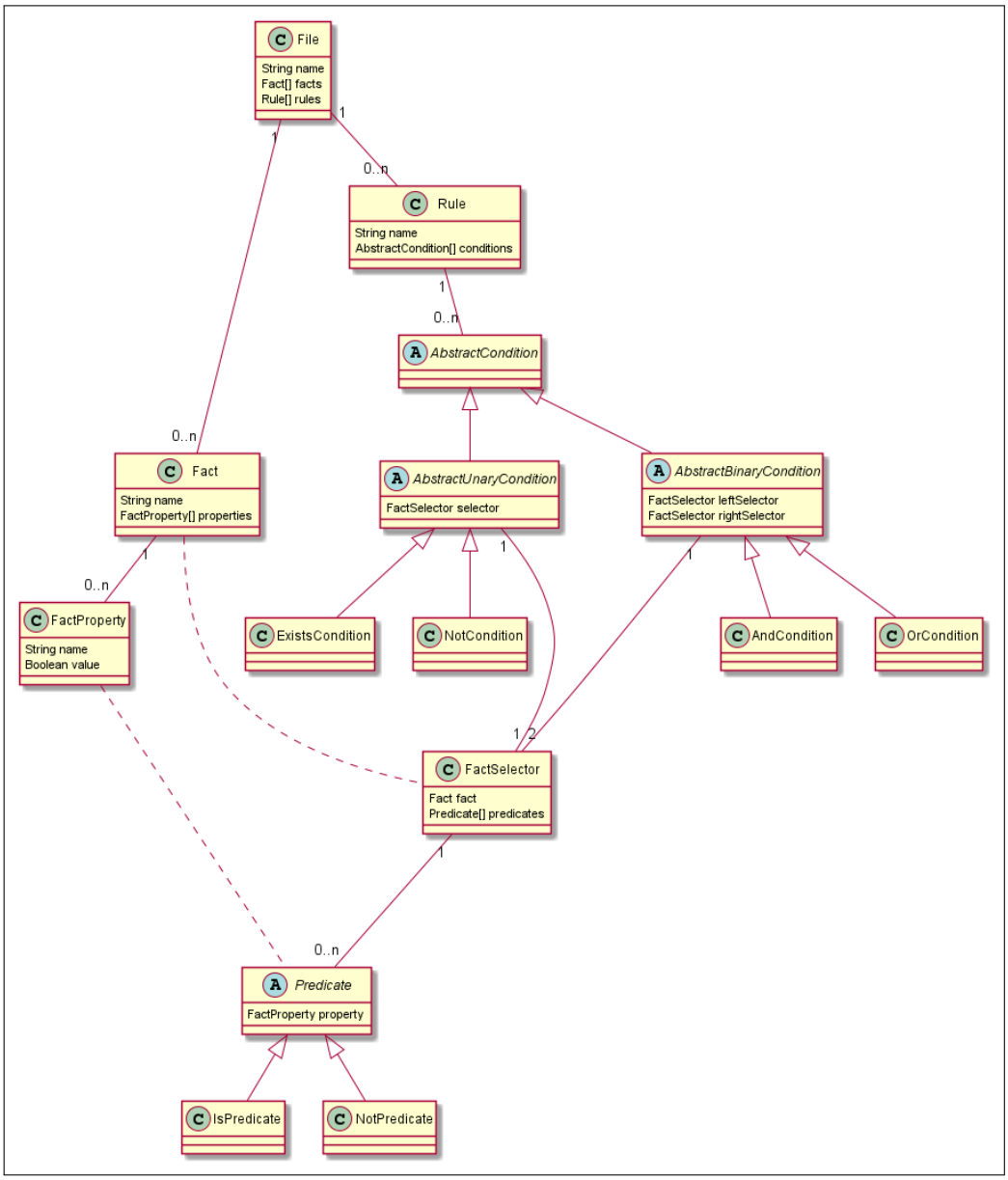


FIGURE 3.1: RSR Concept Hierarchy

Part of the research question is using projections to reason about large files. In order to answer this we needed to simulate a large file. To do this we had to enter a large number of rules. As this becomes tedious we added a number of editing aids including substitute menus to speed up the entry of conditions, as shown in figure 3.4. This image, shows that before I had to select an ExistsCondition concept, and thereafter select the Fact for the condition. After adding the substitute menu, I could immediate select the Fact I wanted and it would then automatically be wrapped with an ExistsCondition node. I could immediately select the Fact and the

We also added some intentions to invert incorrectly added conditions.

Finally, we added a constraint to scope the fact properties in predicates to the Fact chosen in the FactSelector. This made it much easier to select properties in the predicates as indicated in figure 3.5. In the figure you can see that before the scoping constraint it

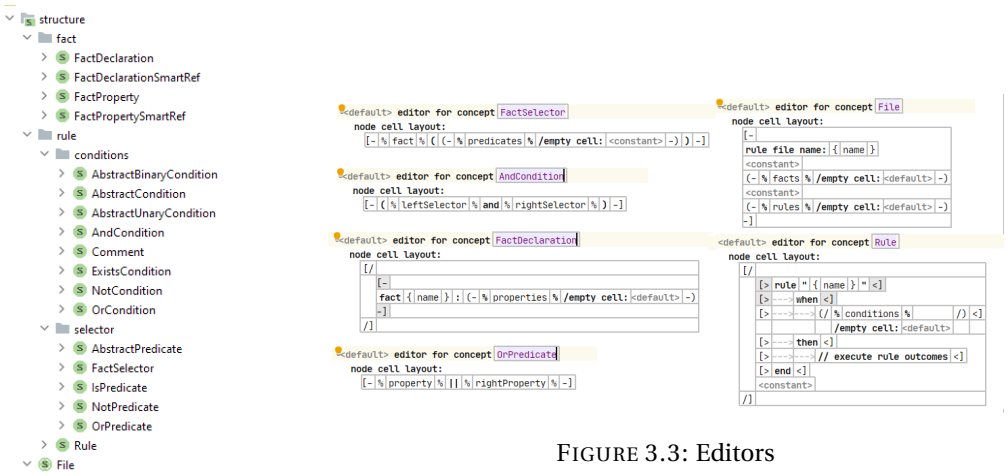


FIGURE 3.2: RSR

FIGURE 3.3: Editors

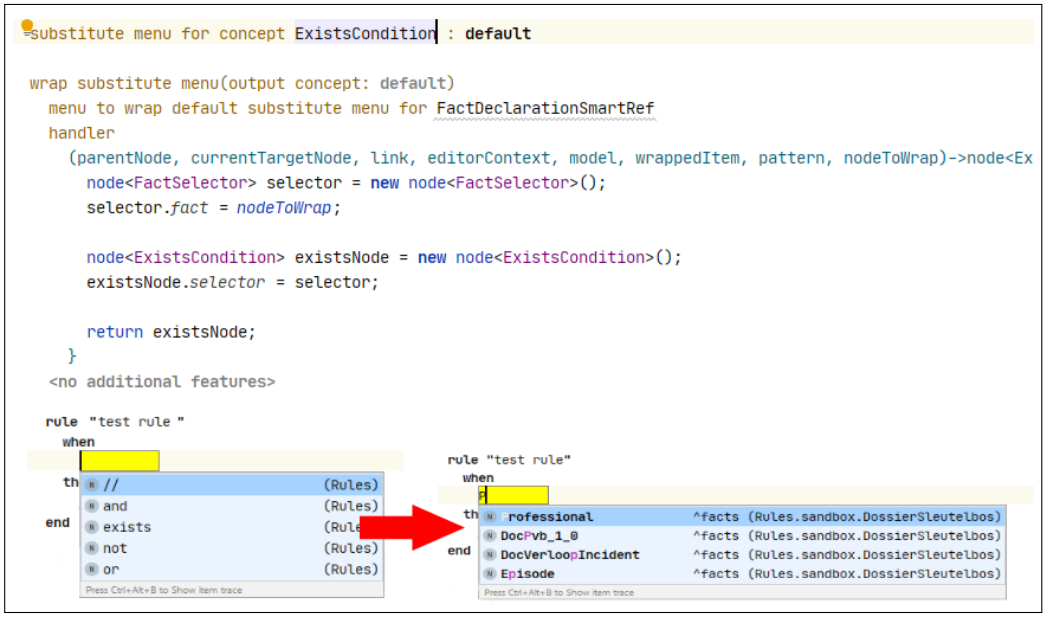


FIGURE 3.4: RSR Substitute Menu

showed a list with dozens of potential FactProperties, that represented all the FactProperties in the Model. After the constraint is added it only shows the two properties associates with the Fact from the FactSelector.

Thus, we have described the entire implementation of the Really Simple Rules Language.

After implementing the language we wrote a program with a large number of rules. This program on which we will experiment with the different projections. An example of our default Drools like text projection is show in figure 3.6.

The alternative projections will be discussed in the results section 4.2.

FIGURE 3.5: RSR Scoping Constraint

3.2.2 Drools-Lite Language

The RSR was useful as an initial language, however is suffered two major Issues. Firstly, it's limitations as a language were so great that it was not able to handle many necessary scenarios. Secondly, our projections would have to be validated by developers with Drools experience. For this reason we needed to create a projectional language that was much closer to the Drools language.

Our next Language, Drools-Lite, contains many more of the features of Drools. Our method of selecting the features was to implement the examples that are delivered with Drools (including the corrupt politician example shown in section 2.1.2). We would implement just enough features to complete the examples. Whenever we had any queries about how to design the concepts we referred to our analysis of the Drools Language, shown in appendix F. The preliminary design we achieved using this method is shown in figure 3.7. Later, there were a number of places we diverged a little or merged or decoupled concepts where we thought it would simplify the code.

Rule File the rule file level statements contains Facts, Globals and Rules. It also contains semantically unimportant empty lines.

Fact a fact has a type property. The type property is implemented using a ClassifierType from the MPS BaseLanguage. This allows the file to refer to BaseLanguage classes implemented in the same solution or to java JAR files. We created a smart reference object for this, to take advantage of built in MPS UI functionality. A smart reference is a node with a single reference of 1:1 cardinality. The editor builders know how to select which nodes in scope to display to the developer if one uses this object rather than directly referencing the node to which it refers.

In the default editor we use a Read Only Model Access Cell to allow the user to select the type by it's name. However, once selected it displays the fully qualified name.

FactProperty In RSR we had FactProperties as children of Facts. Now that our Facts refer to actual classes, via the Classifier Type, now our FactProperties have to reflect this. To do this, the Concept itself only has a reference to an InstanceMethodDeclaration, MPS BaseLanguage's definition of a Method signature. We scoped the concept to only show

```
rule file name: DossierSleutelbos

fact Dossier : hasRunningEpisode , isWvGGZ
fact DroolsContext : << ... >>
fact Episode : isCM , done ,
fact Milestone : cmDecisionStep , finished ,

rule "0"
  when
    Dossier (  )
    DroolsContext (  )
  then
    // nothing
end

rule "[WVGGZ/CM] Start CM procedure"  "
  when
    Dossier ( isWvGGZ , !hasRunningEpisode  )
  then
    // nothing
end

rule "[WVGGZ/VCM] dossier_Start_VCM  "
  when
    ( Dossier ( isWvGGZ , !hasRunningEpisode  ) or ( Episode ( isCM , !done  ) and
        Milestone ( cmDecisionStep , finished  ) ) )
  then
    // nothing
end
```

FIGURE 3.6: RSR program

properties associated with a selected Fact. Drools interacts with Java objects as if they are Java Beans. To simulate this we limited the scope of the properties to just getters, i.e. methods that start with “get” or “is” and used a behavior to make sure they displayed without the “get” or “is” prefix. We also made a smart reference for this concept.

Another option for achieving this is that we could have just wrapped the Classifier-Type and referenced its related InstanceMethodDeclarations. We would have then had to limit the functionality of these items from the BaseLanguage. Whilst this allows the functionality we wished for, we feel our construction is a little more decoupled that we think properly reflects the structure of the language. Perhaps if we were to redo this we would have taken the other approach.

Global Our globals are very simple they have a name and they have a Type, taken from the BaseLanguage. We have a smart reference, so that it can be used in rules. The reference extended Expression from the BaseLanguage. This is, so that we could use it in the Right hand side of the rules.

Rule Our rules are made of three children, an Attribute collection, a Right Hand Side and a list of Conditions that make up the left hand side. We created a component to describe the rule editor, for reuse, as we imagined that we would wrap this in later projections.

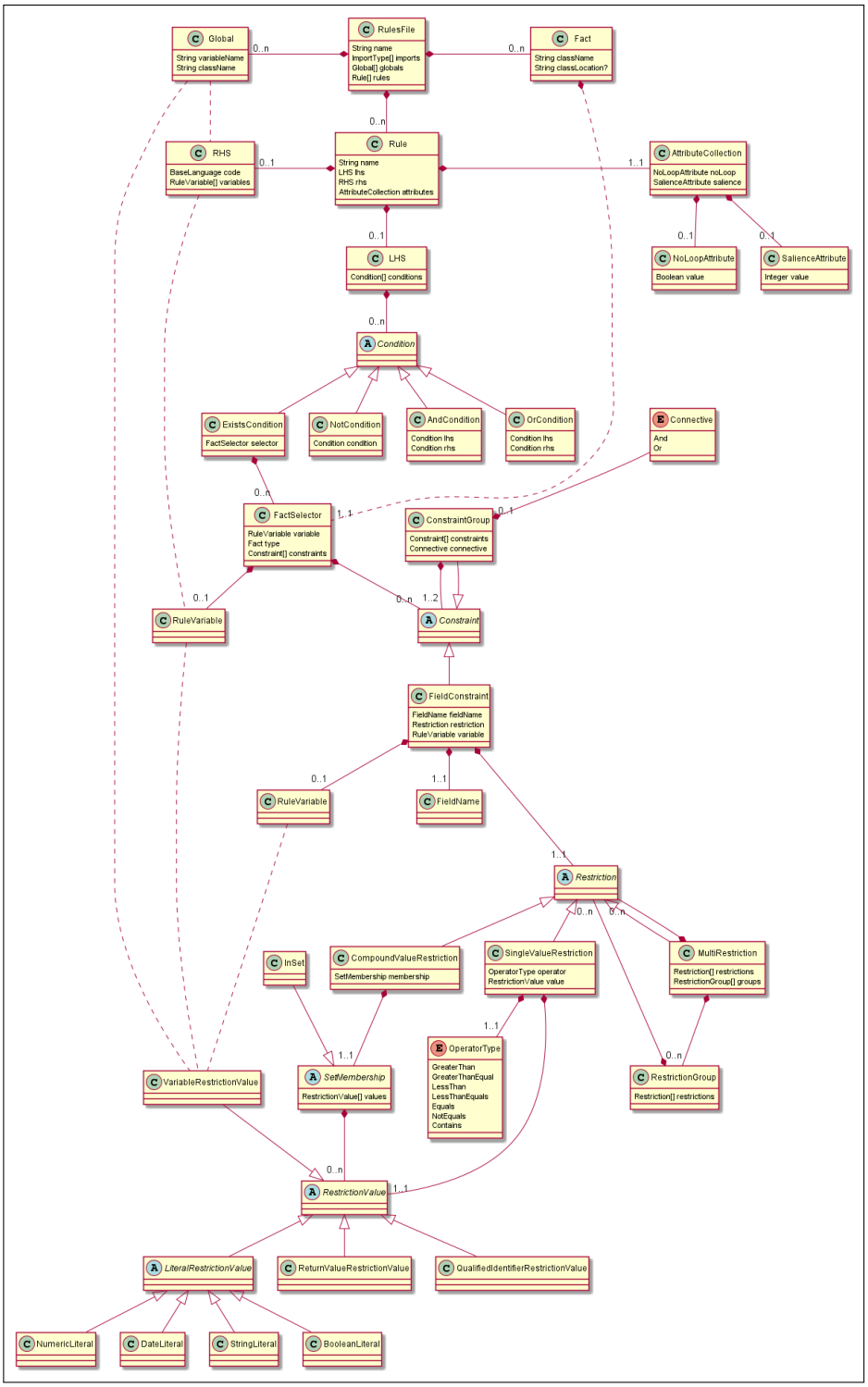


FIGURE 3.7: Drools-Lite Structure

Rule Variables although rule variables do not get created until a FactSelector or a FieldConstrain is used, it is worth mentioning them here, as implicitly they belong to a rule. A Rule variable only has a name and a type. We also create a smart reference for it, so it can be used elsewhere within the rule. Like the global, it extends Expression, to be useable in the Java code of the right hand side.

Right Hand Side The right hand side of the rule is for the most part is Java code. To implement this, we made the right hand side of the rule a single StatementList. A StatementList, from the BaseLanguage, as a list of Statements, also from the BaseLanguage, that keeps track of, amongst other things, scope.

There are a number of non-java, Drools specific items that have to go in the right hand side. Items that had to useable within the righthand side were global variables, rule variables and Drools specific functions. These all extend Expression, so that they can be seamlessly used.

The Drools specific Methods that are required are Insert, InsertLogical, Modify, Delete and Halt.

```
rule "set up"
  when
    $s : Student(  )
  then
    modify( $s ) { setCumlaude( false ) };
    Program program = $s.getProgram();
    insert(  program ) ;

    foreach course in program.getCourses() {
      insert(  course ) ;
    }
end
```

FIGURE 3.8: RHS

Figure 3.8 shows some of the features discussed for the right hand side as shown in our default projection. The right hand side is represented by the text shown between the `then` keyword and the `end` keyword. In the figure one can see examples of plain Java code, such as assigning to the variable `program` and the `foreach` loop. We can also see that Drools-Lite rule variable `$s` is inserted into the Java statements. We have also highlighted the drools specific methods placed in the code, in this case **`modify`** and **`insert`**

RuleAttributes Rule Attributes is a container to hold all of the attributes that are applicable to a rule. Initially, we have only implemented the No-Loop and Salience attributes. These attributes can only be activated through two intentions we added to the Rule Concept. We can see, on line 2 in figure 3.9, an example of the salience attribute added to a rule on line 2.

Some things to note about figure 3.9. We added line numbers to this figure to make it easier to talk about. The keywords `rule` on line 1, `when` on line 3, `then` on line 6, and `end`

on line 8 have no meaning in the abstract syntax. They are added to give the developer the same look and feel as a standard Drools file.

```
1 rule "Rule #1"
2   salience 10
3   when
4     Program( faculty in ( Faculty.Law, Faculty.FNWI ) )
5     $s : Student( avg >= 8 ) || not Result( grade <= 7 && > 8 )
6   then
7     modify( $s ) { setCumlaude( true ) };
8 end
```

FIGURE 3.9: Rule

Left Hand Side This is a collection of conditions. There are four types of conditions. And, Or, Not and Exists. And, OR, and Not have one or two children who are also conditions. Exists contains a FactSelector.

We added dynamic braces, to only show braces around a condition if it is a child of another condition. This adds visual clarity, without adding unnecessary clutter. we also added some intentions to make it easy to switch between Exists and Not conditions.

On line 4 in figure 3.9, the whole line represents an Exists Condition. Line 5 shows an OR condition with containing an Exists and a Not Condition. The default editor, through an intention, can make the Exists condition explicit with an `exists` keyword. However, the standard practice with Drools developers is to make this implicit, so this is how we show it here.

FactSelector This always has a reference to a fact. These facts are `Program` in line 4 of figure 3.9, and `Student` and `Result` from line 5.

Optionally, the fact selector can be bound to a variable. In figure 3.9 line 5 the FactSelector referencing the `Student` Fact is bound to the `$s` variable.

The FactSelector also contains a list of constraints on FactProperties, that all must return true in order for the FactSelector to return true.

Constraints We have three types of constraints. And and Or constraints contain other constraints. The FieldConstraints places restrictions on FactProperties.

FieldConstraints A FieldConstraint refers to a FactProperty and can be bound to a variable. It also has a restriction applied to that FactProperty. Using a substitute menu we wrapped the FactProperty smart reference. This automatically creates the FieldConstraint from a FactProperty selection by the developer.

There are several types of Restriction and several types of values that they can restrict.

Restriction Values restriction values that a property can be compared with are as follows. Literal Restrictions: These are Integer, Float, String, DateTime and Boolean. Variable Restrictions: these can be global variables, rule variables referring to facts, from the FactSelector, or variables from other FieldConstraints. Return Value: this is for comparing to anything that can be expressed as an expression, which includes referring to constants or values behind qualified identifiers.

In figure 3.9 on line 4 we have the return values `Faculty.Law` and `Faculty.FNWI`. on line 5 the literal values `7` and `8`.

Restrictions A SingleValueRestriction compares a FactProperty against a value. A MultiRestriction compares a FactProperty against multiple values, not necessarily using the same comparison for each value. A SetMembership restriction checks if a FactProperty is a member of a group.

In figure 3.9 on line 4 a SetMembership restriction is shown with the `in ( Faculty.Law, Faculty.FNWI )` text. Line 5 in the first FactSelector there is the SingleValue restriction `avg >= 8`. The second FactSelector shows a MultiRestrictions `grade <= 7 && > 8`.

Thus, we have described the pertinent implementation details of the Drools-Lite language.

3.2.3 Wireframes

There are some potential projections we have conceived for which there is not sufficient time to implement. We would like for these to be assessed and thus would like them to appear as real as possible to the assessors.

Our solution to this conundrum, is to develop these presentations in a wireframing tool. The Wireframe tool we choose was Axure[64]. We chose thus as we had previous experience of the product. Also, it is available to students for free.

After much discussion, we settled on two possible projectional programming aids: Truth table and circuit diagram. We will discuss these in more details in the results section.

3.3 Method: Survey

The validity of the the Prototype was tested using a survey. If a survey is not well designed then it could lead to invalid or irrelevant outcomes. As well as describing the design and procedure of the survey, we also outline any threats to its validity in this chapter. Our choice of survey technique is a Questionnaire.

3.3.1 Questionnaire Design

The questionnaire can be found in appendix G. To design the survey of our prototype, we followed a number of rules derived from the works of Bryman[65] and de Vaus[66].

As advised, first we devised a clear introduction to describe the research.

We considered existing questions. With regards to projectional editing, we requested the original questionnaires from three papers[20, 25, 43] pertaining to tools developed using projectional editing. From these questionnaires we found [X] that we considered and decided against using any of them.

When formulating the questions we had the specific research question "Which projections can help developers to get appropriate feedback about rules?" in mind.

The pool of Drools users that we were personally in contact with was incredibly small. Thus we had to rely on responses from strangers. For this reason, we tried to make the questionnaire as quick to finish as possible. This meant we looked particularly hard at removing questions that did not help us to our research goal.

We piloted the questionnaire with both ourselves and our industrial supervisor.

The instructions to each of the questions were tested for clarity, by a non-technical third party.

The only open question was one for which we wished to extract sentiment. Rather than having yes/no questions, where appropriate we applied a Likert scale[67].

The design of survey monkey layout makes sure that questions do not span pages.

The socio-demographic questions (skill level and experience) were left to the end and research based questions were toward at the beginning.

We took care to rework questions that were long, ambiguous, general, or leading to not be so. We also took care to remove jargon, negative wording, and questions that asked about more than one thing.

3.3.2 Participants

The requirement for participants is that they have at least a little experience with using Drools. It was our hope to get a statistically significant number of participants.

3.3.3 Validity

Non-response bias[68] will be addressed by making the questionnaire short and easy to answer. Because of the nature of the participant selection for this survey, it will be difficult to address the bias of self selection caused by voluntary response.

Common method bias, i.e. "variance that is attributable to the measurement method rather than to the construct the measures represent"[69] can be responsible for 25% or more of variable relational influence. As we are only conducting a single survey, we won't be able to do much to prevent this, however we will take the following small precautions. Testing the survey to remove question ambiguity, mood influences, and length issues. Mixing the survey order of questions will be used to mitigate the issues caused by similarity of items, proximity of items, and location of items. We will mitigate survey administration biases by administering some of these questionnaires manually and some online. We will make sure that there are no right or wrong answers and aim toward fact based questions. We will vary the scales of our Likert scales and the types of questions.

The main statistical methods to address this bias, i.e. "Harman's single factor test"[69] and the"marker variable"[70] were found to be lacking in grounding[71]. Marker variable is considered appropriate if used with caution. With the size of our expected returns, it may not be possible to gain a statistically significant outcome.

3.3.4 Pre-test

The first attempt at the survey was sent to our industrial supervisor, who has experience with Drools. We used this to remove ambiguously worded or leading questions and test that the length was truly between 5-10 minutes. This lead to the following changes: [TODO: add changes after we have tested]

3.3.5 Sampling

As within our own professional network we only had acquaintance with (6?) Drools developers, we had to expand our reach to those we did not personally know.

Our approach was first search StackOverflow for question askers and answerers on the subject of Drools. Our preference was to find email addresses, failing that twitter contacts. This proved to be quite limited, especially in attempting to get contact details, 13 email addresses and 6 twitter addresses.

Our next approach was to trawl our LinkedIn connections for anyone with drools as a proclaimed skill. Whilst we had no one in our direct contacts, at one level of separation we found 204 connections. From these we could extract 54 email addresses and 40 twitter addresses, with only a small crossover with the addresses harvested from StackOverflow.

We chose not to expand to third level contacts, as we thought this would be harder to sell as to why they should feel comfortable answering us.

3.3.6 Procedure

The questions, as described in appendix G, was uploaded to Survey monkey.

To encourage response, especially amongst only tangentially known participants, we crafted a short introduction, using techniques designed to enhance response as discussed by amongst others Cialdini[72]. As seen in figure 3.10, the attics discussed by Cialdini, as signposted in table 3.4.

Key	Tactic
1	Short option for those with no time
2	Credentials matter
3	Recognition, (this might backfire as I hardly remember any of my LinkedIn connections)
4	Consistency, they reported they have Drools experience, so they must live up to it
5a&b	Social Proof - other people have already answered
6	showing value
7	Special because of scarcity
8	Labelling - “I see you to be a good person”
9	The word “Because” has an outweighed effect
10	Compliment Expertise
11	“Every little helps”
12	point out a fault
13	own the fault
14	ask a favour
15	add inconvenience
16	Rhyming
17	hand written note

TABLE 3.4: persuasion tactics in figure 3.10

These were sent to our list of drools using strangers and we sat back and awaited response.

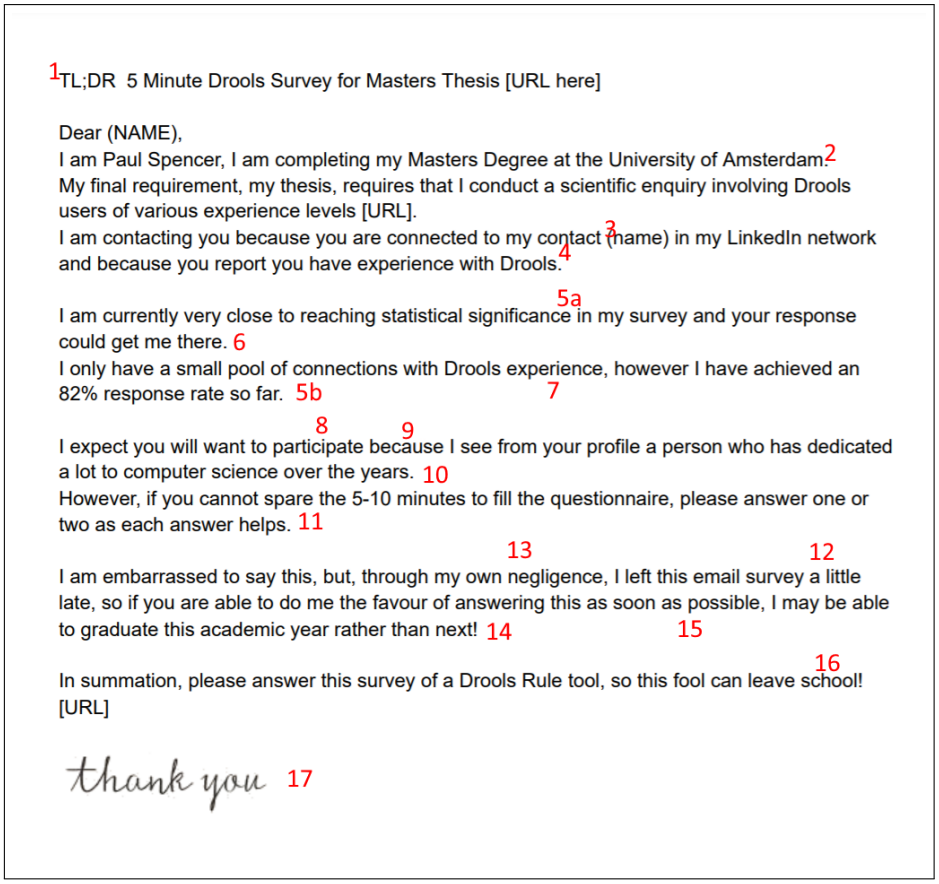


FIGURE 3.10: persuasive introduction.

Chapter 4

Results

> the purpose of abstraction is not to be vague but to create a new semantic level in which one can be absolutly precise.
>
> *The Humble Programmer*
> *Edsger W. Dijkstra*

4.1 Results: Systematic Literature Review

Using a systematic literature review (SLR), following the method described, to answer the question, "What is the current state of Projectional Editing", leads us to the conclusion of - undetermined.

We make this statement because the review design was not appropriate for the problem domain. The SLR was abandoned after the quality assessment stage. We were unable to find a quality assessment checklist that adequately accounted for action design research, which most of the primary studies were. There were some self-identified case studies which in fact were only descriptions of usage of implementations, rather than case studies in a scientific sense.

Therefore what follows should be considered as the results of a Quasi-SLR.

4.1.1 Papers Selected

The details of what is described in this section are logged in appendix B

Figure 4.1 shows the results of the 5 iterations that the search went through. From our initial search using the scholarly search tools out of 173 results we had 50 papers that initially seemed to pass our inclusion and exclusion criteria. From the initial 50, we added 18 papers from a possible 109 in our first iteration of forward and backward snowballing. The next snowballing iteration returned three papers that matched our criteria. The third round of snowballing had no matching papers and thus terminated this stage of selection.

Our final selection iteration involved a deeper scan of to determine of the remaining 71 papers. With this we could reject 12 papers which were not primary research, one paper

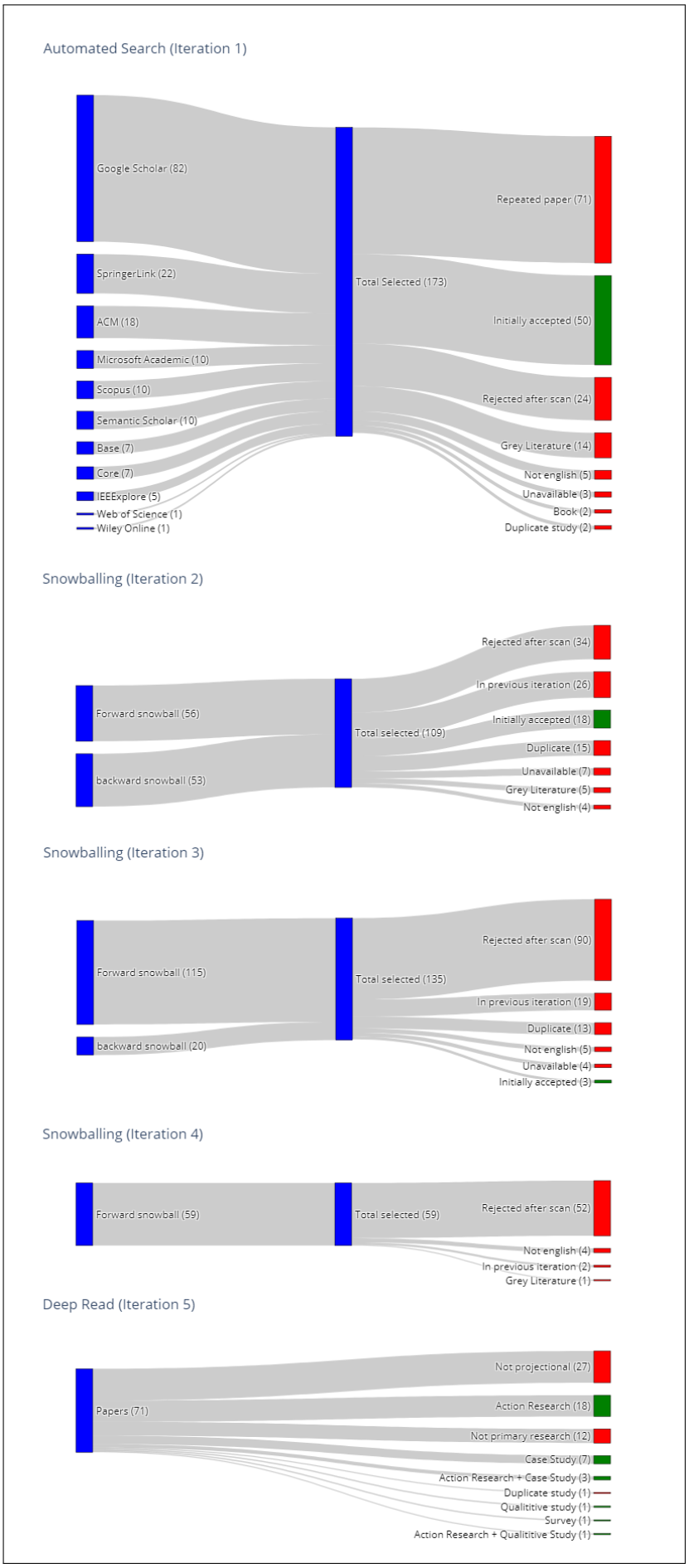


FIGURE 4.1: Search results

that reported a study already represented. There were also 27 papers that were, on closer reading, not about projectional editing.

This left us with 31 papers before the quality assessment filter.

sensitivity and precision

As a curio, we reapproriated Zhang's[55] ideas of sensitivity and precision and applied them to the search engines rather than search strings. The values for sensitivity and precision of the search engines are calculated as follows:

$$sensitivity = \frac{\#\,retrieved\,relevant\,studies}{all\,relevant\,studies}\,100\%$$

$$precision = \frac{\#\,retrieved\,relevant\,studies}{\#\,studies\,retrieved}\,100\%$$

Table 4.1 show that Google Scholar had the highest sensitivity, returning 22 of the 31 chosen studies. This came at the cost of a very large proportion of false positives. Microsoft Academic and SpringerLink were joint most precise with half of their search results ending up in the final roster. SpringerLink, with the second highest count of documents, second highest sensitivity, and joint highest precision would appear to be the best all around search engine for this field. However, these figures are skewed by several of their articles coming from a single collection specifically about projectional editing.

Search engine/library	original #	selected #	sensitivity	precision
ACM	18	3	10%	16%
BASE	7	3	10%	43%
CORE	7	1	3%	14%
Google Scholar	82	22	71%	27%
IEEExplores	5	2	6%	40%
Microsoft Academic	10	5	16%	50%
Science.gov	0	0	0%	0%
SCOPUS	10	3	10%	30%
Semantic Scholar	10	4	13%	40%
SpringerLink	22	11	35%	50%
Wiley Online	1	0	0%	0%
Web of Science	1	0	0%	0%

TABLE 4.1: Search Engine sensitivity and precision

4.1.2 Quality Assessment

Using the quality assessment checklists, developed by Crombie et al.[73], shown in appendix C we examined the remaining 31 papers which on the surface represented 37 primary studies. As action design research was not represented amongst these checklists we searched for an appropriate quality assessment checklist for these type of primary study. We did not find a suitable checklist, and did not consider ourselves suitably qualified to

make one. Thus we used the case study quality assessment checklist to assess the ADR studies.

We used a rudimentary scoring system of +1 value for positive answers, 0 for “don’t knows”, and -1 for negative answers. We arbitrarily chose that any study with an overall score greater than 0 would be considered high enough quality to be part of our final analysis.

With this scoring and goal we only found 6 out of 37 studies of high enough quality.

We therefore had to decide to change our scoring, go ahead with 6 studies, stop here or ignore the QA findings. Changing the scoring until you get the “right” result felt wrong. 6 studies seems too few to give an overview of a field. Stopping seems to be the correct course for an SLA. However, we decided to create a new Quasi-SLA, that ignores the results of a Quality assessment.

Our reason to continue was that we could not reconcile that 84% of studies that had made it to the recognized scientific journals were not of high enough quality to pass our SLR QA stage. We believe there were two large threats to the validity of the Quality Assessment stage that were too great to ignore. The first being that it was carried out by a single researcher with no previous experience. The other being either that the use of case study checklists is inappropriate for ADR studies or that ADR studies are inappropriate for SLRs.

4.1.3 Analysis

After Identifying the primary studies we extracted data, the details of which are shown in appendix E. A summary is shown in [TODO: lots of Graphs]

4.1.4 Threats to validity

- survey selection
- quality assessment
- data extraction
- search phrase choice
- that sentiment analysis is invalid for scientific papers
- azure sentiment analysis is not calibrated for scientific papers

4.2 Results: Action Design Research

4.2.1 Really Simple Rules

The Really Simple Rules, (RSR), acted as a training ground for our new projections.

Context aware color scheme

After the default text projection, the first projection we made was giving the text a color scheme. This form or augmentation in IDEs is probably the most basic that we see. Available in structured editors since the 1980s[74], syntax highlighting displays text in various colors and fonts according to the meaning of the terms. Syntax highlighting has been found to be useful for comprehension of code, as least for small code bases[75].

Developers at our host organization uses Eclipse or IntelliJ Community Editions to edit code, neither of which have syntax highlighting for Drools, thus the addition of this feature would immediately benefit them. However, IntelliJ IDEA, already provides this feature for Drools. In order to offer another visual augmentation that we considered should be useful we extended the color scheme to indicate whether the selection is looking for a positive or negative match. This is shown in figure 4.2.

FIGURE 4.2: Context aware color scheme

Facts that are contained by NotConditions and FactProperties that are part of a NotPredicate are highlighted in Red. ExistConditions and IsPredicates have their content colored green. We did not test whether this improved understanding.

Summary projection

Our next projection allows developers to have a quick overview of rules and complexity of those rules. Figure 4.3 shows that the developers are able to get an overview of both the number of rules and the number of facts in each of the rules.

The building of this rule only required adjusting two editors. The rule count and fact count were added to the File editor using Read Only Model Access, to just count the descendants of the file that are rules and facts. The rule editor was adjusted to only show the title of the rule and, again using the model access, the count of the descendants of the rule that were facts.

```
rule file name: DossierSleutelbos  rule count 152  fact count 357

0 : # facts:  2
Dossierdetails kunnen inzien : # facts:  1
Dossiers samenvoegen : # facts:  0
[*] dossier_NieuweNotitie : # facts:  1
[*] dossier_StuurVeiligeMail : # facts:  1
Dossier verwijderen : # facts:  1
[HV ] dossier_Sluiten : # facts:  1
[HV ] dossier_Afdoen : # facts:  1
[HV ] dossier_Actualiseren : # facts:  1
[WVGGZ/VO] Bewerk NAW in WVGGZ VO voor meldmedewerkers : # facts:  3
[WVGGZ/IBS_WZD] Bewerk NAW in WVGGZ IBS_WZD : # facts:  1
[WVGGZ/CM] Start CM procedure" : # facts:  1
[WVGGZ/CM] Verzamel Stuurgegevens : # facts:  2
[WVGGZ/CM] Wijzig Stuurgegevens Voor Afronden Medische Verklaring : # facts:  3
[WVGGZ/CM] dossier_Act_Opstellen_CMMedischeVerklaring : # facts:  2
[WVGGZ/CM] dossier_Act_Onderteken_MedischeVerklaring : # facts:  3
[WVGGZ/CM] dossier_TerugzettenAfgerondeCMMedischeVerklaring : # facts:  5
```

FIGURE 4.3: Summary Projection

Whilst, this may look like a report, that any language workbench could create, the file name and all of the names of the rules are, in fact, still editable in this projection.

Filtering

The nature of business rules lends them to some projectional options that would not make sense with other programming styles. because of the small, independent nature of the rules filtering in particular lends itself to the business rules style. When looking at how to understand large files, we sought other domains than programming that handle large volumes of items. The domain of data has a long history of handling large volumes. Amongst their two most used tools for exploration are Sorting and Filtering. On top of the semantic meaning of the ordering of the rules, we also did not imagine a good use case for sorting rules. Thus de decided to implement a filtering projection.

Whilst filtering has been used in other places in the coding pipeline, such as in deciding on what code completion to present[76], and version control visualization[77], we were unable to find any research on applying filtering directly to code files. Thus, we think what we present here is an original implementation.

When thinking about how business rules are related, one of the first things we look at is rules that examine the same facts or fact properties. Thus these seemed the most obvious items to filter on. We created a projection where if the developer filtered by a Fact or a Fact Property, then the projection would only filter out all rules that did not contain the item. On top of this once the rules were filtered it would only show Facts and Fact properties that were used by those rules.

In our implementation, shown in figure 4.4, we show three places where we use intentions to filter the code. The first is an intention on a Fact. The outcome of choosing this filter is shown on the righthand side of figure 4.4. The second intention is on a FactProperty. As the FactProperty is a child of a Fact and we enabled that children could also show intentions, we also see an intention to filter on the parent Fact type. The third highlighted intention is on a FactProperty Reference. It also shows an intention for a Fact Reference in the FactSelector that holds the FactProperty reference as a child.

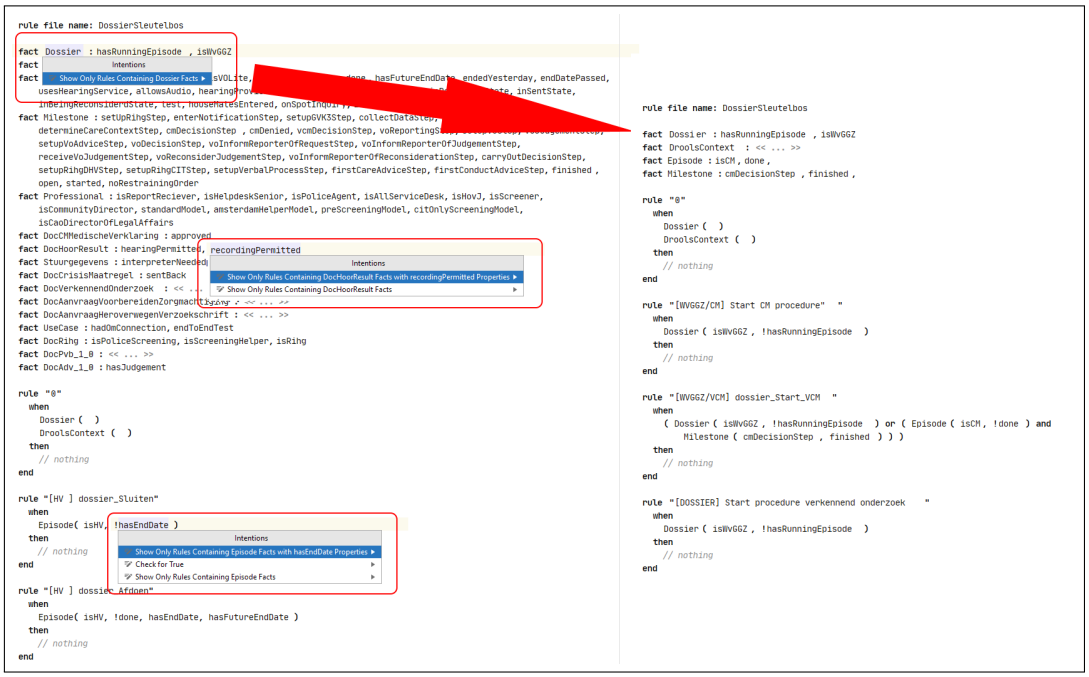


FIGURE 4.4: Filtering Projection

One of our guidelines for ourselves was, as much as possible, to build our projections as separate languages, non-invasively extending RSR. Our first approach at the filtering, we failed on this count, by adding properties to Fact and FactProperty Concepts, to determine whether they were visible.

Our next approach created subclasses of Fact, FactProperty and File. This however requires running a macro on the code file to migrate Facts, FactProperties and Files, to FilteredFacts, FilteredFactProperties, and FilteredFiles. This means that the file could only be used by other languages that extend the filtered language.

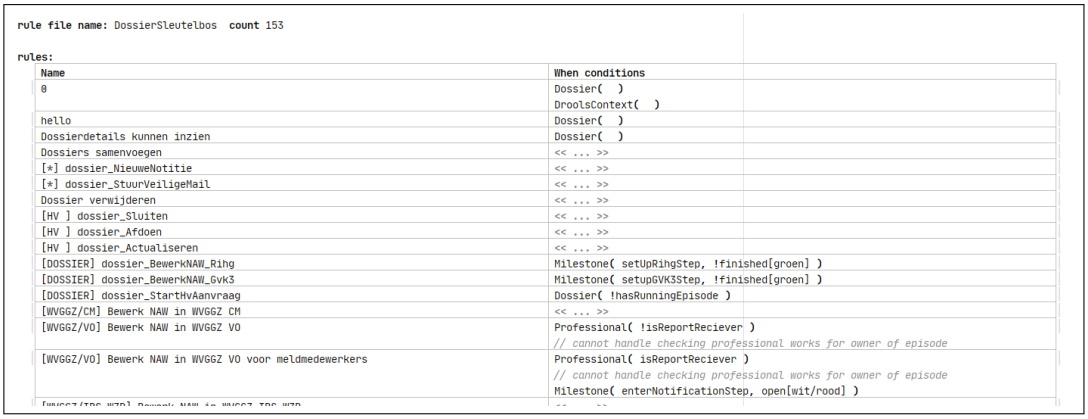
Our Final approach was to add a Filter Concept and have that reference the filtered nodes, and have the editors make the visibility calculations based on this singleton node. Whilst more complex, this removed the need for invasive changes and allowed other languages to combine with the filtering language.

Whilst this filtering is a handy projection, it does break Dijkstra's rule "the purpose of abstraction is not to be vague but to create a new semantic level in which one can be absolutely precise."[78]. The Summary projection could have been extended, so that the inspector contained all of the details of a selected rule. This projection has no way of containing the whole code whilst a filter is applied. However, so long as there is a clear indication that a filter is applied, then I do not see this as more of a problem than code collapsing found in most modern day editors.

Table

Thus far our projections have been textual ones that can be imagined with other language workbenches. Creating a table will be our first non-parseable projection. Our choice for this projection is based on the of Miller's[1] observations about the number of items people can retain in their memory. Based on this observation then the counter-measure to

this is to have fewer items off the screen and therefore in the developers memory.



rule file name: DossierSleutelbos count 153

rules:

Name	When conditions
0	Dossier( )
	DroolsContext( )
hello	Dossier( )
Dossierdetails kunnen inzien	Dossier( )
Dossiers samenvoegen	<< ... >>
[*] dossier_NieuweNotitie	<< ... >>
[*] dossier_StuurVeiligeMail	<< ... >>
Dossier verwijderen	<< ... >>
[HV] dossier_Sluiten	<< ... >>
[HV] dossier_Afdoen	<< ... >>
[HV] dossier_Actualiseren	<< ... >>
[DOSSIER] dossier_BewerkNAW_Ring	Milestone(setUpRingStep, !finished[groen])
[DOSSIER] dossier_BewerkNAW_Gvk3	Milestone(setupGVK3Step, !finished[groen])
[DOSSIER] dossier_StartHvAanvraag	Dossier(!hasRunningEpisode)
[WVGGZ/CM] Bewerk NAW in WVGGZ CM	<< ... >>
[WVGGZ/VO] Bewerk NAW in WVGGZ VO	Professional(!isReportReciever)
	// cannot handle checking professional works for owner of episode
[WVGGZ/VO] Bewerk NAW in WVGGZ VO voor meldmedewerkers	Professional(isReportReciever)
	// cannot handle checking professional works for owner of episode
	Milestone(enterNotificationStep, open[wit/rood])

FIGURE 4.5: Table Projection

Figure 4.5, shows our rudimentary first table. This simple table has only the Name property and the when children of the rules in the file. This is implemented using the table extension, in the MPS-Extension Plugin, created by Sascha Lißon.

Cross-Tab

Our next tabular projection is a cross-tab inspired by a decision table. The idea for this is that the previous table does not give any visual queues as to how rules are related. With a cross-tab one can easily see which rules are using the same Facts.

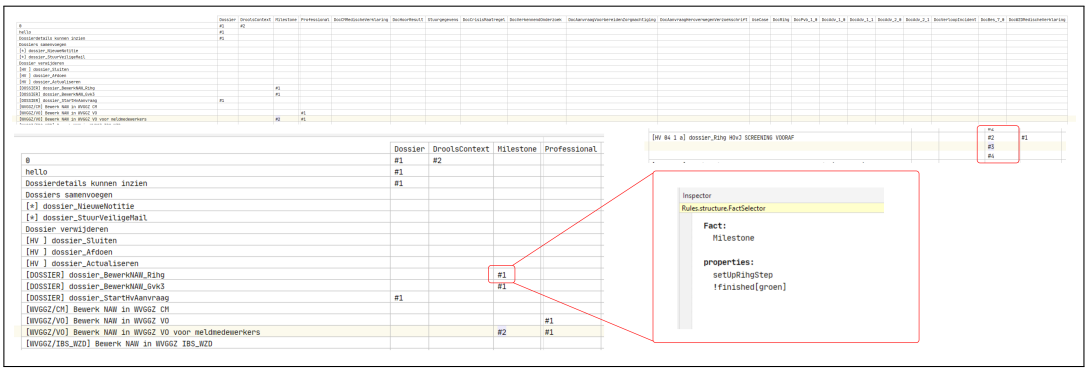


FIGURE 4.6: Cross-Tab Projection

Figure 4.6 Shows our implementation of the cross tab. At the top we can see an immediate problem with a cross-tab, and that is, if we have the whole file included the table will be very sparse. Figure 4.6 also has a close-up of a cell showing a rule using three Fact-Selectors that reference the same fact. The other close-up shows that all the details of the selected fact are available in the inspector.

The sparse table would not be a problem if the columns are thin enough to keep the table in a single screen width.

Everything is editable in this table, including deleting the fact from the rule. Most of the editing was provided by default by either MPS or the table plugin. An extra editing feature we added to this table was the ability to delete a Fact from the file, and thus deleting

all references to it from all the rules in the file, by deleting a Fact column column. The code shown in figure 4.7, shows how we can walk the trees in each rule to delete unary conditions and convert the non-deleted side of binary conditions into unary conditions.

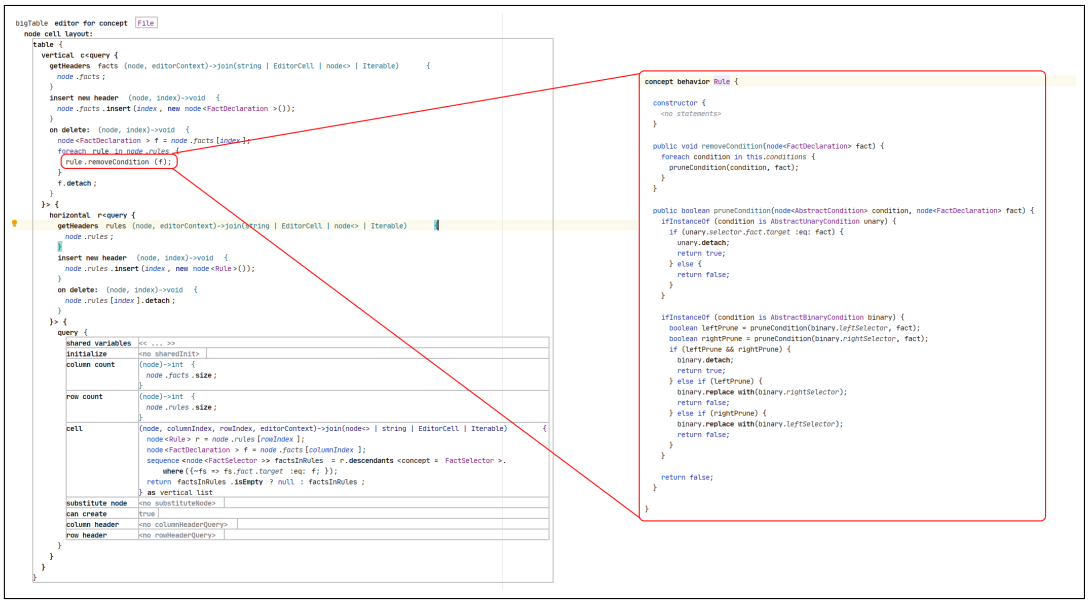


FIGURE 4.7: Table fact deletion code

Here ends our experiments in the RSR language.

4.2.2 Drools-Lite

Our next experiments were with projections with the Drools-Lite language. As described in the section 3.2.2, is an implementation that is much closer to the full Drools language. These are the projections that we will present to experienced Drools developers for evaluation.

Of the learnings from the RSR language, one we felt needed to be fixed to aid understanding was the sparseness of the tables. By implementing the principle of maximising cohesion, we discovered we could reduce the sparseness issue. Thus, as a precursor to our projections, we extended Drools-Lite with a new language that contained one structural item, the Rule Collection. The rule collection sits at the file level and holds a collection of rule statements. The idea behind this is that rules that are related can be placed in the rule group so that it is easier to examine them together. This language also had a default editor, and intentions to move rules in and out of groups.

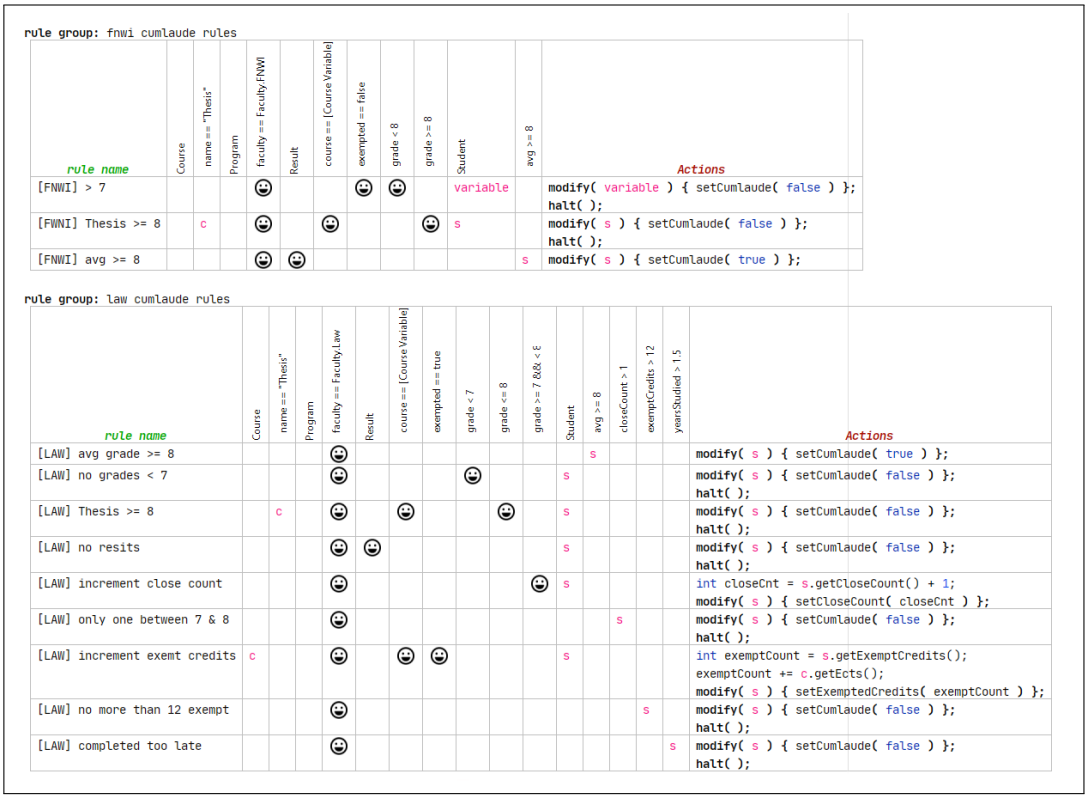
Decision Table

As the Drools Language is analogous to a series of it-then-else statements, then perhaps it's best visual equivalent is the decision table. It has long been shown that decision tables are a "powerful aid in programming, documentation, and in effective man-to-man and man-to-machine communications"[79].

We designed our table, shown in figure 4.8, to include some of the lessons learned from the RSR CrossTab that was demonstrated in figure 4.6. The RSR language taught us that

sparseness in tables is exacerbated through wasting of visual real estate. In the crosstab table, horizontal scrolling was necessary in part due to the column widths. The columns were wide as the name of the Fact was displayed horizontally.

The Drools-Lite language allows for much longer selection criteria on Fact Properties, so we had to design the display with this in mind. This screen real estate needed to be saved, as our decision table required a column to show the consequences of the selections, which in itself would be a wide column. Our solution to this was to develop a vertically orientated header cell and use indentation to indicate if the cell is referring to just the Fact or a Fact and Fact Property combination. The text for the header cells are generated based on the current



rule group: fnwi cumlaude rules

rule name	Course	name == "Thesis"	Program	faculty == Faculty.FNWI	Result	course == [Course Variable]	exempted == false	grade < 8	grade >= 8	Student	avg >= 8	Actions
[FNWI] > 7				☺			☺	☺		variable		modify(variable) { setCumlaude(false) }; halt( );
[FWNI] Thesis >= 8		c		☺		☺			☺	s		modify(s) { setCumlaude(false) }; halt( );
[FNWI] avg >= 8				☺	☺						s	modify(s) { setCumlaude(true) };

rule group: law cumlaude rules

rule name	Course	name == "Thesis"	Program	faculty == Faculty.Law	Result	course == [Course Variable]	exempted == true	grade < 7	grade <= 8	grade >= 7 && < 8	Student	avg >= 8	closeCount > 1	exemptCredits > 12	yearsStudied > 1.5	Actions
[LAW] avg grade >= 8				☺								s				modify(s) { setCumlaude(true) };
[LAW] no grades < 7				☺				☺			s					modify(s) { setCumlaude(false) }; halt( );
[LAW] Thesis >= 8		c		☺		☺			☺		s					modify(s) { setCumlaude(false) }; halt( );
[LAW] no resits				☺	☺						s					modify(s) { setCumlaude(false) }; halt( );
[LAW] increment close count				☺						☺	s					int closeCnt = s.getCloseCount() + 1; modify(s) { setCloseCount(closeCnt) };
[LAW] only one between 7 & 8				☺									s			modify(s) { setCumlaude(false) }; halt( );
[LAW] increment exemt credits	c			☺		☺	☺				s					int exemptCount = s.getExemptCredits(); exemptCount += c.getEcts(); modify(s) { setExemptedCredits(exemptCount) };
[LAW] no more than 12 exempt				☺										s		modify(s) { setCumlaude(false) }; halt( );
[LAW] completed too late				☺											s	modify(s) { setCumlaude(false) }; halt( );

FIGURE 4.8: Decision table projection

Because this projection presents both the left and right hand side of the rules, we had to handle the Concept that spans both of these - the RuleVariable. As the RuleVariable can be bound and used on the LHS as well as being used on the RHS, we had to find a way of representing this. This was achieved by allowing a variable name to be used in the cell that represented the Fact or FactProperty it represented. This lead to a happy visual design choice. With variables now being represented in the cells, we could no longer represent the cell being selected with an 'X', as this could lead to confusion as to the meaning. Projectional editing does not require meaning to be communicated with ASCII text. Thus we decided to represent selection with an image, and personal preference and a misspent youth lead us to the smiley face as that indicator.

The rule names and actions are editable through the default functionality of the MPS extension. Adding a selection criteria to a rule occurs through an intention attached to the associated cell, as is also the case for binding a variable.

The major drawback of this design is that editing a rule with an as yet non-existent

selection criteria became very clunky. If the rule we wished to edit already existed in the table we had to use an intention to extract it from the group change the criteria and place it back in. At this point the table would automatically adjust the column headings.

This design was examined by experts in the questionnaire.

SpreadSheet

The domain specific language for the finance world is the spreadsheet. One study estimated that 90% of computers had a spreadsheet on them[80]. It has been suggested that Dan Bricklin's VisiCalc is the reason for the success of PC's in The office. VisiCalc was succeeded by Lotus 1-2-3, which in turn was succeeded by Microsoft Excel as the dominant Spreadsheet program in the workplace.

This level of familiarity to a paradigm lead us to try to design a projection that had the same look and feel of an Excel spreadsheet. This design can be seen in figure 4.9. To this end we created a design where the selection criteria could be directly edited in the cell, as highlighted in the figure.

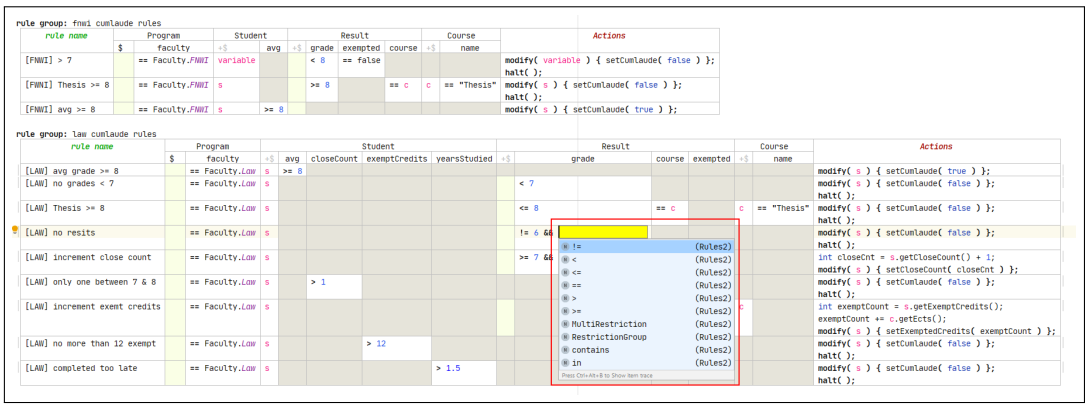


FIGURE 4.9: Spreadsheet projection

In this design each row is a rule, each column is for a variable or a property of a fact. If a property is selected then the selection criteria is in the appropriate cell. Unselected cells are indicated by a grey/beige color. The RHS of the rule appears in the Actions column. To add as yet unused facts or fact properties, or remove existing ones, can be achieved with intentions, as shown in figure 4.10.

This Design also allowed us to have more than one selector for the same FactProperty, this being important for our host organizations code. This is demonstrated in the figure 4.11.

This design was examined by experts in the questionnaire.

Here ends our experiments in the Drools-lite language.

4.2.3 Wireframe

After brainstorming several ideas to present as wireframes to experts as possible projectional aids to understanding we chose two. We discuss them briefly in this section.

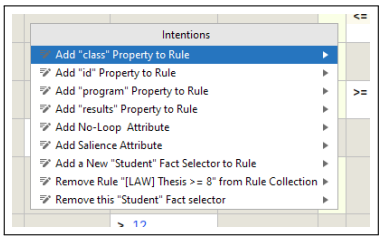


FIGURE 4.10: Intention

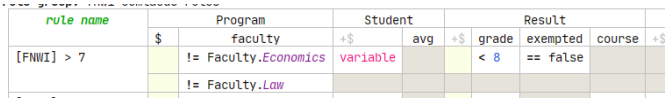


FIGURE 4.11: Two of same Property

Truth Table

We decided to produce this example as we had had experience of building truth tables to confirm the validity of Drools rules in our work, thus we had an n of 1 whom we knew would find this projection useful.

The truth table seemed apt for the LHS of the Drools rule as in essence it is a boolean function. Wittgenstein popularized the truth table in the Tractatus Logico-Philosophicus[81]. It is so widely used in mathematics and computer science, that we do not feel the necessity to explain its use further. Because of the combinatorial explosive nature of truth tables, with 2^n possible combinations, thus we would limit display to a max of 6 variabiables and only show the paths that lead to the RHS being executed.

FIGURE 4.12: Truth Table Projection

Figure 4.12 shows how we designed this to look. The user experience would be that the rule is selected and the developer presses the up and down arrow keys to step through the different true (highlighted in green) and false (highlighted in red) fact selections that result in a true outcome.

We presented this design to our experts through the questionnaire to be validated.

Circuit Diagram

Our last projection design wanted to present a part of projectional editing that we had heretofore only mad minimal use of. That is the use of Graphics which can be manipulated to change the AST.

We chose a logic circuit. The logic circuit represents a boolean operations as NOT, OR, XOR and AND Gates with their inputs and outputs being inputs to other gates. In our design, shown in figure 4.13 the input wires to the gates are the Facts or FactProperties referenced in the LHS.

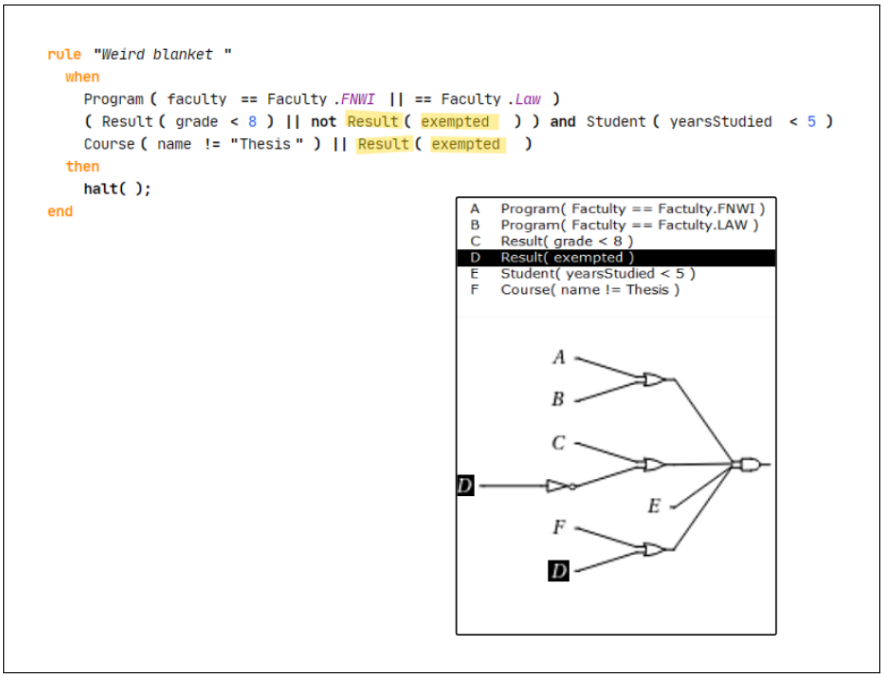


FIGURE 4.13: Circuit Diagram Projection

The user experience is that once the rule is selected, the developer, by pressing the up and down arrow keys, can step through the different fact selections (highlighted in yellow) and shown in the circuit diagram, thus showing how the facts relate to each other.

This design is also presented in the questionnaire for validation.

4.3 Results: Survey

4.3.1 Population Selection

We initially had two sources for our Experienced Drools users to send our survey to. From LinkedIn we selected users who were at one degree of separation from us and listed Drools in their skills. From StackOverflow we selected users who had asked or answered questions about Drools.

As in these two websites the users do not tend to list their contact details, some investigation was required. From the initial selection, whose size we did not record we harvested email accounts, and failing that twitter accounts.

A few days into our survey we read a paper that described the use of academic papers as a population of expertise. We used Google Scholar to look up Drools papers from the previous 2 years. After skimming the papers to ensure that it was specifically about or using the Drools language we harvested emails

On the second and fourth day of the survey two subjects forwarded the weblink to the survey to mailing lists. One, a developer from the core Drools team, sent it to a list of known Drools consultants. The other sent it internally in his company. both the subjects who sent the survey to their mailing list forwarded links to version C of the survey.

We had created 4 versions of the questionnaires to a combat single source bias. We distributed the surveys to the subjects harvested from LinkedIn and StackOverflow evenly. Because of the overrepresentation of Survey C, we distributed the subjects harvested from academic papers evenly over Surveys A, B and D.

The collection result can be seen in figure 4.14. What we see here is that the method of collection did not have much of an impact on return rates. whilst StackOverflow had a higher rate, the number of people contacted was so small that a small addition of respondents has an outsized effect on the proportion.

The first three pie charts represents the collection methods over which we had control. These three represented 24 of our 30 completed questionnaires. The last pie chart represents 6 completed and 4 partially completed questionnaires, that were returned from the surveys sent on by our initial participants. We do not know the size of the starting population of these lists. Thus this pie chart only shows the ratio of partial to completed results.

In summary, a survey reached known 154 participants, of which 24 completed it, for a Response Rate of 15.5%. In addition, an unknown amount of participants were reached through mailing lists, returning a further 6 completed surveys.

4.3.2 Participant demography

Responses came from around the world. Figure 4.15 shows the location of the respondents were concentrated in Europe, the exceptions being the USA, Israel, and Singapore. Italy and the Netherlands provided the largest number of responses, with 7 and 5 respectively.

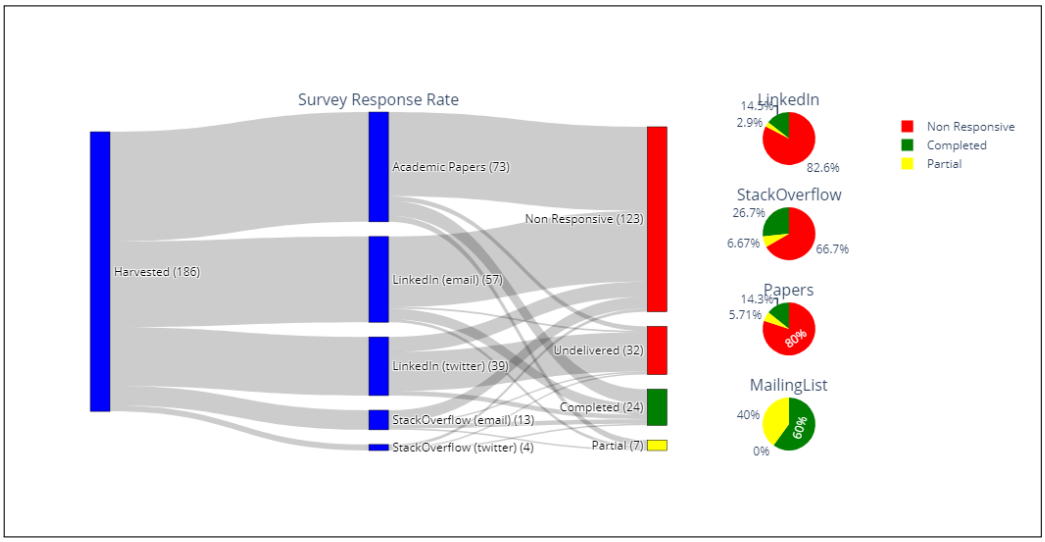


FIGURE 4.14: Survey Participants

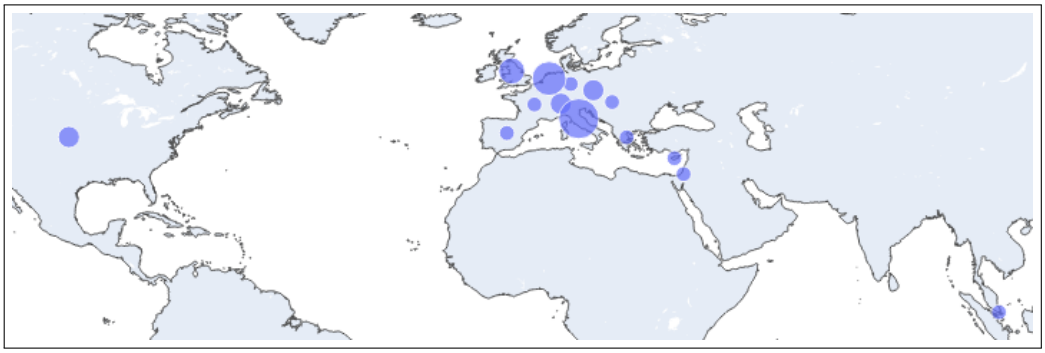
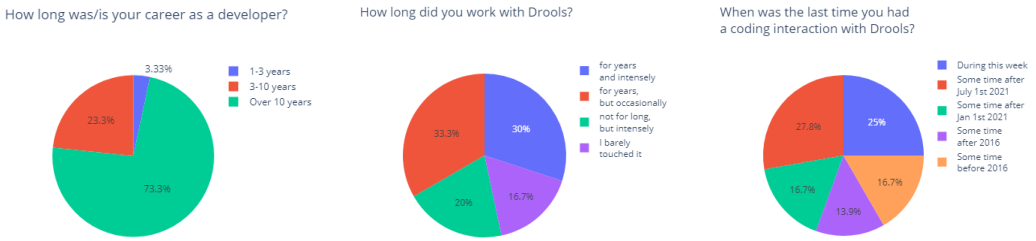


FIGURE 4.15: Survey Locations



(A) a (B) b (C) c

FIGURE 4.16: Subject Experience

The experience of our subjects was quite high. As can be seen in 4.16, most of our subjects have over 10 years programming experience. 17% of our recipients had a low experience of Drools, and 30% were very experienced. Over half of our recipients have used Drools in the previous 6 weeks with only 17% not having used Drools for more than 5 years.

Chapter 5

Discussion

5.1 Threats to Validity

5.1.1 Construct Validity

5.1.2 Internal Validity

5.1.3 External Validity

5.1.4 Reliability

5.1.5 Repeatability vs Reproducibility

5.1.6 Method improvement

Chapter 6

Implications to research and practice

6.1 Implications to research

6.2 Future research directions

6.3 Implications to practice

Chapter 7

Conclusion

We have built our projections as an aid to the understanding of Drools rules. This DSL extension includes many different ways to look at and interact with large code bases, as well as presenting options to deal with the complexity of individual rules. This means that they must be [TODO: PROPERTIES THAT AIDS UNDERSTANDING]. Our questionnaires show that we have reached that aim. Since developing our projections we have used them to model complex rules in our host organization.

Two factors lead to our success. First was the flexibility and extensibility of the MPS tool which presented the ability to develop and extend DSLs very efficiently. If we had tried this project without this tooling we would have [TODO: Finish our thoughts] Second [TODO: Finish our thoughts]

In this paper we described our work with first translating the Drools DSL into a projectional language followed by our explorations of projections. We discussed the advantages and disadvantages of the different projections we created and analysed experienced developers reactions to them.

Whilst we are convinced our projections [TODO: finish our thoughts]

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Appendix A

Protocol Validation Checklist

The protocol will be validated using the checklist in table A.1, which was adapted from Kitchenham's book Evidence-Based Software Engineering and Systematic Reviews[54].

Components	Questions
Background	Is the motivation for the review clearly stated and reasonable?
Research questions	Do these address a topic of interest to practitioners and/or researchers? Are they clearly stated?
Search strategy	Is the strategy justified and is it likely to find the right primary studies without the reviewers having to check or read a large number of irrelevant papers? Has the strategy been validated?
Study selection	Are the inclusion/exclusion criteria clearly defined and related to research questions? Is a validation process specified? Is there a process for handling marginal and uncertain papers? Is there a process for managing multiple reports of individual studies?
Quality of primary studies	Is it clear that the outcomes will be used in the later stages of the review? Is a validation process specified? Are criteria for assessing quality provided and justified and appropriate to the anticipated primary study types?
Data extraction	Does the data to be extracted properly address the research questions? Are the methods of recording the data appropriate for the types of data to be extracted? Is a validation process specified? Are there mechanisms for iteration where data is qualitative and categories are not (or cannot be) fully defined in advance of the extraction? Will the process enable the research questions to be answered?
Data aggregation and synthesis	Are the methods proposed for qualitative and quantitative data appropriate? Has consideration been given to combining results across multiple study types? Is the approach to aggregation and synthesis justified concerning appropriate literature?
Reporting	Has this been considered? has sufficient attention been paid to the completeness, general interest, validation, traceability, and the limitations of the review?
Review management	Are the tools that will be used for managing papers, studies, and data specified and appropriate? Is the management of the many-to-many relationship between papers and studies addressed?

TABLE A.1: Protocol Validation Checklist

Appendix B

Systematic Literature Review Log

B.1 Search Description

The papers we found with our automatic search can be found in table B.2. There were 100 unique papers found with the search strings across all of the venues when we used the search string and date restrictions. First we excluded those that were not in English or were unavailable to us. This reduced the count to 94. Next we downloaded each of the papers.

Next we skimmed all of these papers to remove any that were obviously unrelated to projectional editing. This reduced the count to 69.

two of the papers were referring to the same study, which reduced the count to 67.

We then excluded all grey literature, i.e. masters projects, proposals and PhD theses, and also books. This brought us down to 51 papers.

At this point we began our quality assessment.

B.2 Table description

Table B.2 shows the log of the Systematic literature review.

The First column “Paper Title” is the name of the paper as given by the search engine.

The second column “Lib”, indicates the library or search engine through which it was found. The Libraries are Identified by the Keys in table B.1.

Key	Search engine/library	Key	Search engine/library
1	Google Scholar	2	IEEExplores
3	ACM	4	BASE
5	CORE	6	Web of Science
7	Microsoft Academic	8	SCOPUS
9	Semantic Scholar	10	SpringerLink
11	Wiley Online	12	Science.gov

TABLE B.1: Search Engine/Library Key

The third and fourth columns show inclusion and exclusion reasons. As inclusions only rely on one question, “does this paper discuss projectional editing”, the affirmative is indicated by a tick. The exclusion column includes the reason for the exclusion.

The final column “ref”, gives a link to the citations in the separate bibliography for the systematic literature review, found at the end of the Appendices.

Paper Title	lib	in	exclusion	F#	B#
“Filmar, assistir e problematizar” – contribuições à aprendizagem de cálculos	9		not English	X	X
20. Internationales Stuttgarter Symposium	10		book	X	X
A Domain-Specific Language for Payroll Calculations: a Case Study at DATEV	1	✓		0	0
A Domain-Specific Language for Payroll Calculations: An Experience Report from DATEV	1,10	✓	Duplicate	X	X
A Framework for Modernizing Domain-Specific Languages	1	✓	grey	X	X
A Framework for Projectional Multi-variant Model Editors	1,8	✓		0	0
A Generic Projectional Editor for EMF Models	1,7,8,9	✓		2	0
A language-driven Development framework for simulation components to generate simulated environments	1	✓	grey	X	X
A Model-Driven Approach Towards Automatic Migration to Microservices	10	✓		5	0
A survey of Model Driven Engineering in robotics	1	✓		2	2
A Survey on the Design Space of End-User Oriented Languages for Specifying Robotic Missions	1,10	✓		1	5
A survey on the formalisation of system requirements and their validation	1	✓		0	0
A text-based syntax completion method using LR parsing	1			X	X
Activities and costs of re-engineering cloned variants into an integrated platform	1			X	X
AdaptiveVLE: An Integrated Framework for Personalized Online Education Using MPS JetBrains Domain-Specific Modeling Environment	1,2	✓		1	1
Adding Interactive Visual Syntax to Textual Code	3	✓		3	0
An approach to generate text-based IDEs for syntax completion based on syntax specification	1	✓		1	0
An MPS implementation for SimpliC	1	✓	grey	x	x
Blended graphical and textual modelling for UML profiles: A proof-of-concept implementation and experiment	1	✓		0	0
Block-based syntax from context-free grammars	1,3,5	✓		0	2
Bridging the worlds of textual and projectional language workbenches	1	✓	grey	X	X
Classification Algorithms Framework (CAF) to Enable Intelligent Systems Using JetBrains MPS Domain-Specific Languages Environment	2,5	✓		4	0

Paper Title	lib	in	exclusion	F#	B#
Code and Structure Editing for Teaching: A Case Study in using Bibliometrics to Guide Computer Science Research	1,9	✓		2	0
ComPOS - a Domain-Specific Language for Composing Internet-of-Things Systems	1,4	✓	grey	X	X
Concepts of variation control systems	1	✓		9	5
Concise, Type-Safe, and Efficient Structural Diffing	3			X	X
Constructing optimized constraint-preserving application conditions for model transformation rules	1			X	X
Design & Evaluation of an Accessible High-Level Language for Advanced Cryptography	1	✓	grey	X	X
Domain-specific languages for modeling and simulation	1			X	X
Domain-Specific Languages in Practice	10	✓	book	X	X
DSL Based Approach for Building Model-Driven Questionnaires	1,10	✓		0	1
DSS-Based Ontology Alignment in Solid Reference System Configuration	10		unavailable	X	X
Editing Software as Strategy Value	1			X	X
Efficient editing in a tree-oriented projectional editor	1,3,7,8,9	✓		1	0
Efficient generation of graphical model views via lazy model-to-text transformation	1,4	✓		1	0
Efficient usage of abstract scenarios for the development of highly-automated driving functions	1,10	✓	unavailable	X	X
Enabling language engineering for the masses	1,3	✓		2	1
Engineering Gameful Applications with MPS	1,10	✓		0	2
Enhancing development and consistency of UML models and model executions with USE studio	1,3,7,8,9	✓		0	2
Enterprise Information Systems	10		book	X	X
Example-driven software language engineering	1,3	✓		1	2
Exploring Visual Primitives for Authoring Source Code	1		grey	X	X
FASTEN: An Extensible Platform to Experiment with Rigorous Modeling of Safety-Critical Systems	1,10	✓		0	5
FeatureCoPP: unfolding preprocessor variability	1,3			X	X

Paper Title	lib	in	exclusion	F#	B#
FeatureVista: Interactive Feature Visualization	1			X	X
Filling Typed Holes with Live GUIs	3	✓		0	5
First-class concepts: reifying architectural knowledge beyond the dominant decomposition	1,3	✓		0	1
FORMREQ 2020	1,2,8		book	X	X
Gentleman: a light-weight web-based projectional editor generator	1,3,4,7,8,9	✓		0	0
GPP, the Generic Preprocessor	1			X	X
Improving the usability of the domain-specific language editors using artificial intelligence	1	✓	grey	X	X
Incremental Flow Analysis through Computational Dependency Reification	1,2	✓		0	2
Incrementalizing Static Analyses in Datalog	1	✓	grey	X	X
Integrating the Common Variability Language with Multilanguage Annotations for Web Engineering	1			X	X
Integrating UML and ALF: An Approach to Overcome the Code Generation Dilemma in Model-Driven Software Engineering	10	✓		0	0
Javardise: a structured code editor for programming pedagogy in Java	1	✓		0	0
JetBrains MPS as Core DSL Technology for Developing Professional Digital Printers	1,10	✓		0	0
JetBrains MPS: Why Modern Language Workbenches Matter	1,7,10	✓		0	1
Learning Data Analysis with MetaR	1,10	✓		0	0
Lipschitz-like property relative to a set and the generalized Mordukhovich criterion	6			X	X
Macros for Domain-Specific Languages	3			X	X
Mechanizing metatheory interactively	1	✓	grey	X	X
Migrating Insurance Calculation Rule Descriptions from Word to MPS	1,10	✓		0	0
Model Driven Software Engineering Meta-Workbenches: An XTools Approach	1,5	✓		0	0
Model-based safety assessment with SysML and component fault trees: application and lessons learned	1,10	✓		8	0
Model-Driven Development for Spring Boot Microservices	1,5	✓	grey	X	X
n Challenges for Software Language Engineering	1			X	X
On preserving variability consistency in multiple models	1,3			X	X

Paper Title	lib	in	exclusion	F#	B#
On the Need for a Formally Complete and Standardized Language Mapping between C++ and UML	1			X	X
On the Understandability of Language Constructs to Structure the State and Behavior in Abstract State Machine Specifications: A Controlled Experiment	1			X	X
On the use of product-line variants as experimental subjects for clone-and-own research: a case study	1			X	X
PAMOJA: A component framework for grammar-aware engineering	1	✓		0	1
Programming Robots for Activities of Everyday Life	1	✓	grey	X	X
Programming tools for intelligent systems	1	✓	grey	X	X
Projecting Textual Languages	1,10	✓		0	1
Rule-based and user feedback-driven decision support system for transforming automatically-generated alignments into information-integration alignments	5		unavailable	X	X
Semi-Automatische Deduktion von Feature-Lokalisierung während der Softwareentwicklung: Masterarbeit	5		not English	X	X
Should Variation Be Encoded Explicitly in Databases?	1			X	X
SLang: A Domain-specific Language for Survey Questionnaires	1	✓		0	0
SpecEdit: Projectional Editing for TLA+ Specifications	1,4,7	✓		0	0
Specifying Software Languages: Grammars, Projectional Editors, and Unconventional Approaches	1,2,4,5,7,8,9	✓		0	6
Teaching Language Engineering Using MPS	10	✓		0	0
Teaching MPS: Experiences from Industry and Academia	1,10	✓		0	1
Teasy framework: uma solução para testes automatizados em aplicações web	1	✓	not English	X	X
The Art of Bootstrapping	10	✓		3	0
The state of adoption and the challenges of systematic variability management in industry	1			X	X
Toward a domain-specific language for scientific workflow-based applications on multicloud system	1,11			X	X
Towards a Universal Variability Language	1	✓	grey	X	X

Paper Title	lib	in	exclusion	F#	B#
Towards Multi-editor Support for Domain-Specific Languages Utilizing the Language Server Protocol	10	✓		5	0
Towards Ontology-based Domain Specific Language for Internet of Things	1,3	✓		0	0
Towards projectional editing for model-based SPLs	3,4,7,8,9	✓		3	0
Tychonis: A model-based approach to define and search for geometric events in space	1			X	X
Type-Directed Program Transformations for the Working Functional Programmer	1	✓		0	0
Understanding Variability-Aware Analysis in Low-Maturity Variant-Rich Systems	1			X	X
Untangling Mechanized Proofs	3			X	X
Variability representations in class models: An empirical assessment	1,3			X	X
Visual design for a tree-oriented projectional editor	1,3,4,7,8,9	✓	Duplicate	X	X
What do practitioners expect from the meta-modeling tools? A survey	1,7,8,9	✓		0	3
Cyrillic named paper 1	1		not English	X	X
Cyrillic named paper 2	1		not English	X	X

TABLE B.2: Systematic review log - search results

Appendix C

Study Quality Assessment Checklist

The Center for Evidence-Based Management (CEBMa) supports the application of evidence-based practices to the field of management and leadership. They have a collection of checklists for assessing different types of studies. These checklists have been adapted from the pocket guide to critical appraisal[73]. We gave used these as the basis of our quality assessment checklists.

C.1 Critical Appraisal of a Case Study

#	Appraisal questions	Yes	Can't tell	No
1	Did the study address a focused question/issue?			
2	Is the research method (study design) appropriate for answering the research question?			
3	Are both the setting and the subject's representative concerning the population to which the findings will be referred?			
4	Is the researcher's perspective clearly described and taken into account?			
5	Are the methods for collecting data clearly described?			
6	Are the methods for analyzing the data likely to be valid and reliable? Are quality-control measures used?			
7	Was the analysis repeated by more than one researcher to ensure reliability?			
8	Are the results credible, and if so, are they relevant for practice?			
9	Are the conclusions drawn justified by the results?			
10	Are the findings of the study transferable to other settings?			

TABLE C.1: Case Studies Quality Assessment Checklist

C.2 Critical Appraisal of a Qualitative Study

#	Appraisal questions	Yes	Can't tell	No
1	Did the study address a focused question/issue?			
2	Is the research method (study design) appropriate for answering the research question?			
3	Was the context clearly described?			
4	How was the fieldwork undertaken? Was it described in detail? Are the methods for collecting data clearly described?			
5	Could the evidence (fieldwork notes, interview transcripts, recordings, documentary analysis, etc.) be inspected independently by others?			
6	Are the procedures for data analysis reliable and theoretically justified? Are quality-control measures used?			
7	Was the analysis repeated by more than one researcher to ensure reliability?			
8	Are the results credible, and if so, are they relevant for practice?			
9	Are the conclusions drawn justified by the results?			
10	Are the findings of the study transferable to other settings?			

TABLE C.2: Qualitative Studies Quality Assessment Checklist

C.3 Critical Appraisal of a Survey Study

#	Appraisal questions	Yes	Can't tell	No
1	Did the study address a focused question/issue?			
2	Is the research method (study design) appropriate for answering the research question?			
3	Is the method of selection of the subjects (employees, teams, divisions, organizations) clearly described?			
4	Could the way the sample was obtained introduce (selection) bias?			
5	Was the sample of subjects representative concerning the population to which the findings will be referred?			
6	Was the sample size based on pre-study considerations of statistical power?			
7	Was a satisfactory response rate achieved?			
8	Are the measurements (questionnaires) likely to be valid and reliable?			
9	Was the statistical significance assessed?			
10	Are confidence intervals given for the main results?			
11	Could there be confounding factors that haven't been accounted for?			
12	Are the findings of the study transferable to other settings?			

TABLE C.3: Survey Studies Quality Assessment Checklist

C.4 Critical Appraisal of a Cohort or Panel Study

#	Appraisal questions	Yes	Can't tell	No
1	Did the study address a focused question/issue?			
2	Is the research method (study design) appropriate for answering the research question?			
3	Were there enough subjects (employees, teams, divisions, organizations) in the study to establish that the findings did not occur by chance?			
4	Was the selection of the cohort/panel based on external, objective, and validated criteria?			
5	Was the cohort/panel representative of a defined population?			
6	Was the follow up of cases/subjects long enough?			
7	Were objective and unbiased outcome criteria used?			
8	Are objective and validated measurement methods used to measure the outcome?			
9	Is the size effect practically relevant?			
10	How precise is the estimate of the effect? Were confidence intervals given?			
11	Could there be confounding factors that haven't been accounted for?			
12	Are the findings of the study transferable to other settings?			

TABLE C.4: Cohort or Panel Studies Quality Assessment Checklist

Appendix D

Study Quality Assessment Results

In this appendix we present the data for the findings of the Quality assessment stage of the SLR. The occurred after the initial search engine selections, the three snowballing iterations and the final deep read for classification.

Naturally, this table only reports on primary studies. Where a paper reports on more than one study the paper title appears multiple times, with the type of study in parenthesis. If we had multiple papers reporting on the same study, they have already been removed.

We separated the studies into their types. When the authors self reported a type, even if we were not in agreement with them we categorised these as such. The study types were survey, case study, action design research, and qualitative study. for the sake of table width we refer to action design research as ADR.

The question assessments are based on the assessment criteria presented in Appendix C. However these criteria do not have a checklist for Active Design Research. After much research we did not find an adequate checklist for ADR, so we used the case study checklist. After concluding the Quality assessment we had to conclude either that this checklist was not a valid interrogation of ADR studies, or that all 20 ADR studies were bad.

To score the studies, we arbitrarily decided to gave a +1 value for positive answers, 0 for don't knows and -1 for negative answers. We understand that this is a crude system. Note that, whilst most questions answered with "Yes" were considered positive, in the survey checklist, question "Could the way the sample was obtained introduce (selection)bias?", the positively scored answer is "No".

Name	Type	Score	1	2	3	4	5	6	7	8	9	10	11	12
A Domain-Specific Language for Payroll Calculations: a Case Study at DATEV[82]	Case Study	3	Y	Y	Y	?	N	?	N	?	Y	Y	-	-
A Framework for Projectional Multi-variant Model Editors[83]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
A Generic Projectional Editor for EMF Models[84]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
A Model-Driven Approach Towards Automatic Migration to Microservices[85]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
AdaptiveVLE: An Integrated Framework for Personalized Online Education Using MPS JetBrains Domain-Specific Modeling Environment[86]	ADR	3	N	?	Y	?	Y	Y	N	Y	Y	?	-	-
Adding Interactive Visual Syntax to Textual Code[87]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
Blended graphical and textual modelling for UML profiles: A proof-of-concept implementation and experiments[88]	Qualitative Study	8	Y	Y	Y	Y	?	Y	?	Y	Y	Y	-	-
Block-based syntax from context-free grammars[88]	Case Study	-3	N	?	?	N	N	?	N	?	Y	?	-	-
Classification Algorithms Framework (CAF) to Enable Intelligent Systems Using JetBrains MPS Domain-Specific Languages Environment[89]	ADR	3	N	?	Y	?	Y	Y	N	Y	Y	?	-	-
DSL Based Approach for Building Model-Driven Questionnaires (Action Research)[90]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
DSL Based Approach for Building Model-Driven Questionnaires (Qualitative Study1)[90]	Qualitative Study	-2	N	?	Y	N	?	?	N	?	?	?	-	-
DSL Based Approach for Building Model-Driven Questionnaires (Qualitative Study2)[90]	Qualitative Study	-2	N	?	Y	N	?	?	N	?	?	?	-	-
Efficient editing in a tree-oriented projectional editor[91]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
Efficient generation of graphical model views via lazy model-to-text transformation[92]	ADR	0	N	?	?	N	Y	Y	N	Y	?	?	-	-
Engineering Gameful Applications with MPS[93]	ADR	-6	N	?	N	N	N	?	N	?	?	N	-	-
FASTEN: An Extensible Platform to Experiment with Rigorous Modeling of Safety-Critical Systems[94]	ADR	-4	N	?	N	?	N	?	N	?	?	?	-	-

Name	Type	Score	1	2	3	4	5	6	7	8	9	10	11	12
Gentleman: a light-weight web-based projectional editor generator[95]	ADR	-5	N	?	N	?	N	?	N	?	?	N	-	-
Integrating UML and ALF: An Approach to Overcome the Code Generation Dilemma in Model-Driven Software Engineering[96]	ADR	-5	N	?	N	?	N	?	N	?	?	N	-	-
Javardise: a structured code editor for programming pedagogy in Java[97]	ADR	-5	N	?	N	?	N	?	N	?	?	N	-	-
JetBrains MPS as Core DSL Technology for Developing Professional Digital Printers[98]	Case Study	-6	N	?	N	N	N	?	N	?	?	N	-	-
Learning Data Analysis with MetaR[99]	ADR	-4	N	?	Y	N	N	?	N	?	?	N	-	-
Migrating Insurance Calculation Rule Descriptions from Word to MPS[100]	Case Study	-3	N	?	Y	N	N	?	N	?	?	?	-	-
Model-based safety assessment with SysML and component fault trees: application and lessons learned (Case study1)[101]	Case Study	-4	Y	?	N	N	N	?	N	?	?	N	-	-
Model-based safety assessment with SysML and component fault trees: application and lessons learned (Case study2)[101]	Case Study	-2	Y	?	Y	N	N	?	N	?	?	N	-	-
Model-based safety assessment with SysML and component fault trees: application and lessons learned (Action Research)[101]	ADR	-3	N	?	Y	N	N	?	N	?	?	?	-	-
Papyrus for gamers, let's play modeling[102]	ADR	-4	N	?	?	N	N	?	N	?	?	?	-	-
Projecting Textual Languages (Action Research)[103]	ADR	-5	N	?	N	N	N	?	N	?	?	?	-	-
Projecting Textual Languages (Case Study)[103]	Case Study	-6	N	?	N	N	N	?	N	?	?	N	-	-
SpecEdit: Projectional Editing for TLA+ Specifications (Action Research)[104]	ADR	-2	Y	?	?	N	N	?	N	?	?	?	-	-
SpecEdit: Projectional Editing for TLA+ Specifications (Case Study)[104]	Case Study	-5	N	?	N	N	N	?	N	?	?	?	-	-
Teaching Language Engineering Using MPS[105]	Case Study	3	N	?	Y	Y	N	?	N	Y	Y	Y	-	-
Teaching MPS: Experiences from Industry and Academia[106]	Case Study	0	N	?	Y	Y	N	Y	N	?	?	?	-	-
Tiny Structure Editors for Low, Low Prices (Action Research)[107]	ADR	-5	N	?	?	N	N	?	N	?	?	N	-	-
Tiny Structure Editors for Low, Low Prices (Case Study)[107]	Case Study	-6	N	?	N	N	N	?	N	?	?	N	-	-

Name	Type	Score	1	2	3	4	5	6	7	8	9	10	11	12
Towards Ontology-based Domain Specific Language for Internet of Things[108]	ADR	-6	N	?	?	N	N	?	N	?	?	N	-	-
Type-Directed Program Transformations for the Working Functional Programmer[109]	ADR	-3	Y	Y	N	N	N	?	N	?	?	N	-	-
What do practitioners expect from the meta-modeling tools? A survey[110]	Survey	1	Y	Y	Y	Y*	?	?	Y	Y	N	N	?	N

TABLE D.1: Quality Assessment Results

Appendix E

Data Extraction Results

Study ID	1
Title of Study	A domain-specific language for payroll calculations: A case study at DATEV
Year of Publication	2021
Author(s) Names	M. Voelter, S. Košcejev, M. Riedel, A. Deitsch, and A. Hinkelmann
Source of Study	Google Scholar, SpringerLink
Type of Study	Case Study
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	generallearnings -- negative = 23, neutral = 28, positive = 13 evaluation -- negative = 45, neutral = 69, positive = 23 conclusion -- negative = 3, neutral = 10, positive = 4

Study ID	2
Title of Study	A framework for projectional multi-variant model editors
Year of Publication	2021
Author(s) Names	J. Schröpfer, T. Buchmann, and B. Westfecht
Source of Study	Google Scholar, SCOPUS
Type of Study	Action Design Research
Name of Venue	MODELSWARD
Tools in Study	EMF & Ecore
Sentiment	intro -- negative = 2, neutral = 23, positive = 2 conclusion -- negative = 2, neutral = 9, positive = 3

Study ID	3
Title of Study	A generic projectional editor for EMF models
Year of Publication	2020
Author(s) Names	J. Schröpfer, T. Buchmann, and B. Westfecht
Source of Study	Google Scholar, Microsoft Academic, SCOPUS, Semantic Scholar
Type of Study	Action Design Research
Name of Venue	MODELSWARD
Tools in Study	EMF & Ecore
Sentiment	intro -- negative = 12, neutral = 43, positive = 8 conclusion -- negative = 2, neutral = 6, positive = 1

Study ID	4
Title of Study	A model-driven approach towards automatic migration to microservices
Year of Publication	2020
Author(s) Names	A. Bucchiarone, K. Soysal, and C. Guidi
Source of Study	SpringerLink
Type of Study	Action Design Research
Name of Venue	International Workshop on Software Engineering Aspects of Continuous Development and New Paradigms of Software Production and Deployment
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 1, neutral = 15, positive = 3 conclusion -- neutral = 4

FIGURE E.1: Data Extraction Results 1 - 4

Study ID	5
Title of Study	AdaptiveVLE: An integrated framework for personalized online education using MPS JetBrains domain-specific modeling environment
Year of Publication	2020
Author(s) Names	S. Meacham, V. Pech, and D. Nauck
Source of Study	Google Scholar, IEEExplores
Type of Study	Action Design Research
Name of Venue	IEEE Access
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 3, neutral = 17, positive = 2 conclusion -- negative = 2, neutral = 3, positive = 3

Study ID	6
Title of Study	Adding interactive visual syntax to textual code
Year of Publication	2020
Author(s) Names	L. Andersen, M. Ballantyne, and M. Felleisen
Source of Study	ACM
Type of Study	Action Design Research
Name of Venue	Proceedings of the ACM on Programming Languages OOPSLA
Tools in Study	Racket and DrRacket
Sentiment	conclusion -- negative = 1, neutral = 14, positive = 4

Study ID	7
Title of Study	Blended graphical and textual modelling for UML profiles: A proof-of-concept implementation and experiment
Year of Publication	2021
Author(s) Names	L. Addazi and F. Ciccozzi
Source of Study	Google Scholar
Type of Study	Qualitative Study
Name of Venue	Journal of Systems and Software
Tools in Study	Xtext & Ecore
Sentiment	intro -- negative = 6, neutral = 21, positive = 5 projectionalediting -- neutral = 6 discussion -- negative = 18, neutral = 26, positive = 6 conclusion -- negative = 1, neutral = 5, positive = 4

Study ID	8
Title of Study	Classification algorithms framework (CAF) to enable intelligent systems using JetBrains MPS domain-specific languages environment
Year of Publication	2020
Author(s) Names	S. Meacham, V. Pech, and D. Nauck
Source of Study	IEEExplores, CORE
Type of Study	Action Design Research
Name of Venue	IEEE Access
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 2, neutral = 19 evaluation -- negative = 3, neutral = 10, positive = 10 conclusion -- negative = 1, neutral = 6

Study ID	9
Title of Study	DSL based approach for building model-driven questionnaires
Year of Publication	2020
Author(s) Names	A. L. Furtado
Source of Study	Google Scholar, SpringerLink
Type of Study	Action Design Research + Qualitative Study
Name of Venue	Enterprise Information Systems: 22nd International Conference ICEIS 2020
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 4, neutral = 11, positive = 3 Implementations -- negative = 4, neutral = 16 conclusion -- negative = 3, neutral = 5, positive = 2

FIGURE E.2: Data Extraction Results 5 - 9

Study ID	10
Title of Study	Efficient editing in a tree-oriented projectional editor
Year of Publication	2020
Author(s) Names	T. Beckmann
Source of Study	Google Scholar, ACM, Microsoft Academic,SCOPUS, Semantic Scholar
Type of Study	Action Design Research
Name of Venue	Conference Companion of the 4th International Conference on Art, Science, and Engineering of Programming
Tools in Study	sandblocks (Research Project)
Sentiment	intro -- negative = 1, neutral = 7, positive = 2 design -- neutral = 9 conclusion -- negative = 1, neutral = 1, positive = 1

Study ID	11
Title of Study	Efficient generation of graphical modelviews via lazy model-to-text transformation
Year of Publication	2020
Author(s) Names	D. Kolovos, A. De La Vega, and J. Cooper
Source of Study	Google Scholar, BASE
Type of Study	Action Design Research
Name of Venue	Proceedings of the 23rd ACM/IEEEInternational Conference on Model Driven Engineering Languages and Systems
Tools in Study	Picto (Research Project using EGL, Graphviz,PlantUML)
Sentiment	intro -- negative = 3, neutral = 5, positive = 1 evaluation -- negative = 5, neutral = 43, positive = 1 results -- negative = 5, neutral = 34, positive = 5 conclusion -- negative = 1, neutral = 3, positive = 3

Study ID	13
Title of Study	Engineering gameful applications with MPS
Year of Publication	2021
Author(s) Names	A. Bucchiarone, A. Cicchetti, and A. Marconi
Source of Study	Google Scholar, SpringerLink
Type of Study	Action Design Research
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 6, neutral = 20, positive = 5 engineering -- negative = 2, neutral = 34, positive = 7 mpsprojectional -- negative = 2, neutral = 18 lessonslearned -- negative = 11, neutral = 16, positive = 5 conclusion -- negative = 1, neutral = 5, positive = 2

Study ID	15
Title of Study	Fasten: An extensible platform to experiment with rigorous modeling of safety-critical systems
Year of Publication	2021
Author(s) Names	D. Ratiu, A. Nordmann, P. Munk, C. Carlan, and M. Voelter
Source of Study	Google Scholar, SpringerLink
Type of Study	Action Design Research
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 18, neutral = 40, positive = 11 platform -- neutral = 13, positive = 2 discussion -- negative = 3, neutral = 21, positive = 2 discussionMPS -- negative = 14, neutral = 25, positive = 8 conclusion -- negative = 3, neutral = 11, positive = 4

Study ID	16
Title of Study	Gentleman: A light-weight web-based projectional editor generator
Year of Publication	2020
Author(s) Names	L.E. Lafontant and E. Syriani
Source of Study	Google Scholar, ACM, BASE, Microsoft Academic, SCOPUS, Semantic Scholar
Type of Study	Action Design Research
Name of Venue	Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings
Tools in Study	Gentleman (Research Project)
Sentiment	intro -- negative = 8, neutral = 12, positive = 2 editor -- negative = 5, neutral = 43, positive = 5 implementation -- neutral = 10, positive = 1 projections -- neutral = 40, positive = 6 conclusion -- neutral = 4, positive = 2

FIGURE E.3: Data Extraction Results 10 - 16

Study ID	17
Title of Study	Integrating UML and ALF: An approach to overcome the code generation dilemma in model-driven software engineering
Year of Publication	2020
Author(s) Names	J. Schröpfer and T. Buchmann
Source of Study	SpringerLink
Type of Study	Action Design Research
Name of Venue	International Conference on Model-Driven Engineering and Software Development
Tools in Study	ALF (Xtext) + Valkyrie (GMF)
Sentiment	intro -- negative = 4, neutral = 24, positive = 1 discussion -- negative = 4, neutral = 12, positive = 5 UI -- neutral = 9, positive = 2 conclusion -- neutral = 5

Study ID	18
Title of Study	Javardise: A structured code editor for programming pedagogy in Java
Year of Publication	2020
Author(s) Names	A. L. Santos
Source of Study	Google Scholar
Type of Study	Action Design Research
Name of Venue	Conference Companion of the 4th International Conference on Art, Science,and Engineering of Programming
Tools in Study	Javardise (Research Project)
Sentiment	discussion -- negative = 16, neutral = 13, positive = 4 intro -- negative = 11, neutral = 11, positive = 1

Study ID	19
Title of Study	Jetbrains MPS as core DSL technology for developing professional digital printers
Year of Publication	2021
Author(s) Names	E. Schindler, H. Moneva, J. van Pinxten, L. van Gool, B. van der Meulen, N. Stotz,and B. Theelen
Source of Study	Google Scholar, SpringerLink
Type of Study	Case Study
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	CollaborativeDSM -- negative = 5, neutral = 29, positive = 13 conclusion -- negative = 2, neutral = 22, positive = 2 intro -- negative = 1, neutral = 21, positive = 3 MPS -- negative = 9, neutral = 9, positive = 3

Study ID	20
Title of Study	Learning data analysis with metaR
Year of Publication	2021
Author(s) Names	M. Simi
Source of Study	Google Scholar, SpringerLink
Type of Study	Action Design Research
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 1, neutral = 4, positive = 1 languagecompsition -- neutral = 22, positive = 3 MPS -- negative = 9, neutral = 56, positive = 6 conclusion -- negative = 2, neutral = 4, positive = 5

Study ID	21
Title of Study	Migrating insurance calculation rule descriptions from Word to MPS
Year of Publication	2021
Author(s) Names	N. Stotz and K. Birken
Source of Study	Google Scholar, SpringerLink
Type of Study	Case Study
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	intro -- neutral = 5, positive = 1 solutiontechnology -- negative = 20, neutral = 26, positive = 11 evaluation -- negative = 37, neutral = 49, positive = 10 conclusion -- negative = 9, neutral = 8, positive = 7

FIGURE E.4: Data Extraction Results 17 - 21

Study ID	22
Title of Study	Model-based safety assessment with sysml and component fault trees: Application and lessons learned
Year of Publication	2020
Author(s) Names	P. Munk and A. Nordmann
Source of Study	Google Scholar, SpringerLink
Type of Study	Action Design Research + Case Study
Name of Venue	Software and Systems Modeling
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 8, neutral = 11, positive = 6 realisation -- negative = 29, neutral = 46, positive = 11 discussion -- negative = 6, neutral = 4, positive = 2 conclusion -- negative = 4, neutral = 3, positive = 1

Study ID	23
Title of Study	Papyrus for gamers, let's play modeling
Year of Publication	2020
Author(s) Names	A. Bucchiarone, M. Savary-Leblanc, X. L. Pallec, J.M. Bruel, A. Cicchetti, J. Cabot,S. Gerard, H. Aslam, A. Marconi, and M. Perillo
Source of Study	snowball
Type of Study	Action Design Research
Name of Venue	Proceedings of the 23rd ACM/IEEE International Conference on Model-Driven Engineering Languages and Systems: Companion Proceedings
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 5, neutral = 8, positive = 3

Study ID	24
Title of Study	Projecting textual languages
Year of Publication	2021
Author(s) Names	M. V. Merino, J. Bartels, M. van den Brand, T. van der Storm, and E. Schindler
Source of Study	Google Scholar, SpringerLink
Type of Study	Action Design Research + Case Study
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS + Rascal
Sentiment	intro -- negative = 9, neutral = 17, positive = 3 projectionalApproach-- negative = 5, neutral = 128, positive = 4 projectionalSyntax -- negative = 4, neutral = 42 limitation -- negative = 10, neutral = 25, positive = 6 discussion -- negative = 6, neutral = 16, positive = 9 conclusion -- negative = 4, neutral = 14, positive = 5

Study ID	25
Title of Study	SpecEdit: Projectional editing for TLA+ specifications
Year of Publication	2020
Author(s) Names	R. Cuinat, C. Teodorov, and J. Champeau
Source of Study	Google Scholar, BASE,Microsoft Academic
Type of Study	Action Design Research + Case Study
Name of Venue	2020 IEEE Workshop on Formal Requirements (FORMREQ)
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 4, neutral = 16, positive = 6 projectionalEditor -- negative = 7, neutral = 78, positive = 17 lessonslearned -- negative = 4, neutral = 6, positive = 4 discussion -- neutral = 5, positive = 1

Study ID	26
Title of Study	Teaching language engineering using MPS
Year of Publication	2021
Author(s) Names	A. Prinz
Source of Study	SpringerLink
Type of Study	Case Study
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 6, neutral = 25, positive = 8 lessonslearned -- negative = 2, neutral = 12, positive = 2 metalanguages -- negative = 11, neutral = 25, positive = 11 MPSinTeaching -- negative = 14, neutral = 38, positive = 9 selectingTools -- negative = 6, neutral = 11, positive = 6 evaluation -- negative = 9, neutral = 30, positive = 20 conclusion -- negative = 2, neutral = 3, positive = 3

FIGURE E.5: Data Extraction Results 22 - 26

Study ID	27
Title of Study	Teaching MPS: Experiences from industry and academia
Year of Publication	2021
Author(s) Names	M. Barash and V. Pech
Source of Study	Google Scholar, SpringerLink
Type of Study	Case Study
Name of Venue	Domain-Specific Languages in Practice
Tools in Study	Jetbrains MPS
Sentiment	explainingprojectional -- negative = 1, neutral = 6, positive = 1 conclusion -- negative = 1, neutral = 5, positive = 1

Study ID	28
Title of Study	Tiny structure editors for low, low prices! (generating guis from toString functions)
Year of Publication	2020
Author(s) Names	B. Hempel and R. Chugh
Source of Study	snowball
Type of Study	Action Design Research + Case Study
Name of Venue	2020 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)
Tools in Study	Tiny Structure Editor (Research Project)
Sentiment	intro -- negative = 7, neutral = 30, positive = 2 discussion -- negative = 5, neutral = 11, positive = 1

Study ID	29
Title of Study	Towards ontology-based domain specific language for internet of things
Year of Publication	2020
Author(s) Names	E. Negm, S. Makady, and A. Salah
Source of Study	Google Scholar, ACM
Type of Study	Action Design Research
Name of Venue	Proceedings of the 2020 9th International Conference on Software and Information Engineering (ICSIE)
Tools in Study	Jetbrains MPS
Sentiment	intro -- negative = 8, neutral = 22, positive = 5 implementation -- neutral = 20, positive = 2 conclusion -- neutral = 7

Study ID	30
Title of Study	Type-directed program transformations for the working functional programmer
Year of Publication	2020
Author(s) Names	J. Lubin and R. Chugh
Source of Study	Google Scholar
Type of Study	Action Design Research
Name of Venue	10th Workshop on Evaluation and Usability of Programming Languages and Tools (PLATEAU 2019)
Tools in Study	DEUCE
Sentiment	intro -- negative = 7, neutral = 9, positive = 2 implementation -- negative = 13, neutral = 16, positive = 6 usabilityChallenges -- negative = 3, neutral = 5, positive = 2

Study ID	31
Title of Study	What do practitioners expect from the meta-modeling tools? a survey
Year of Publication	2021
Author(s) Names	M. Ozkaya and D. Akdur
Source of Study	Google Scholar, Microsoft Academic, SCOPUS, Semantic Scholar
Type of Study	Survey
Name of Venue	Journal of Computer Languages
Tools in Study	MPS, MetaEdit+, WebGME, GEMS, sirius,Xtext, MS DSL ToolsMelange, GME*
Sentiment	intro -- negative = 11, neutral = 62, positive = 8 editorservice -- negative = 8, neutral = 20, positive = 6 lessonslearned -- negative = 10, neutral = 24, positive = 8 challenges -- negative = 5 toolusage -- negative = 1, neutral = 14, positive = 2 conclusion -- negative = 10, neutral = 20, positive = 3

FIGURE E.6: Data Extraction Results 27 - 31

Appendix F

Drools Concept hierarchy

The concept hierarchy presented on the following pages was extracted and interpreted from Drools railroad diagrams.

The diagram in figure F.1 represents the file level and can be considered the root of Concept Hierarchy. This represents the concepts that are available to the rule file. As the only concept we will examine in depth is the rule, we show some concepts that are shared or are children of, for example, function, query and type declaration.

In our final implementation only the import, global and Rule concepts that were children of the rule file were implemented.

The diagram in figure F.2 shows the children of a rule. Each attribute has a different behavior and structure and are thus all represented separately.

In These diagrams we do not show a concept diagram for the RHS. This is because it would be more or less the concept diagram for Java Statements,with the addition of Rule Variables and some special Drools functions. the concept diagram for a General Purpose Language, like Java, would be orders of magnitude bigger and more complex. Luckily, as MPS allows for almost seamless extension and integration of different languages, we are able to just import JetBrains implementation of Java for the RHS.

The hierarch for the LHS is shown in the diagram in figure F.3. Because of the number of concepts being represented, it may be a little hard to read.

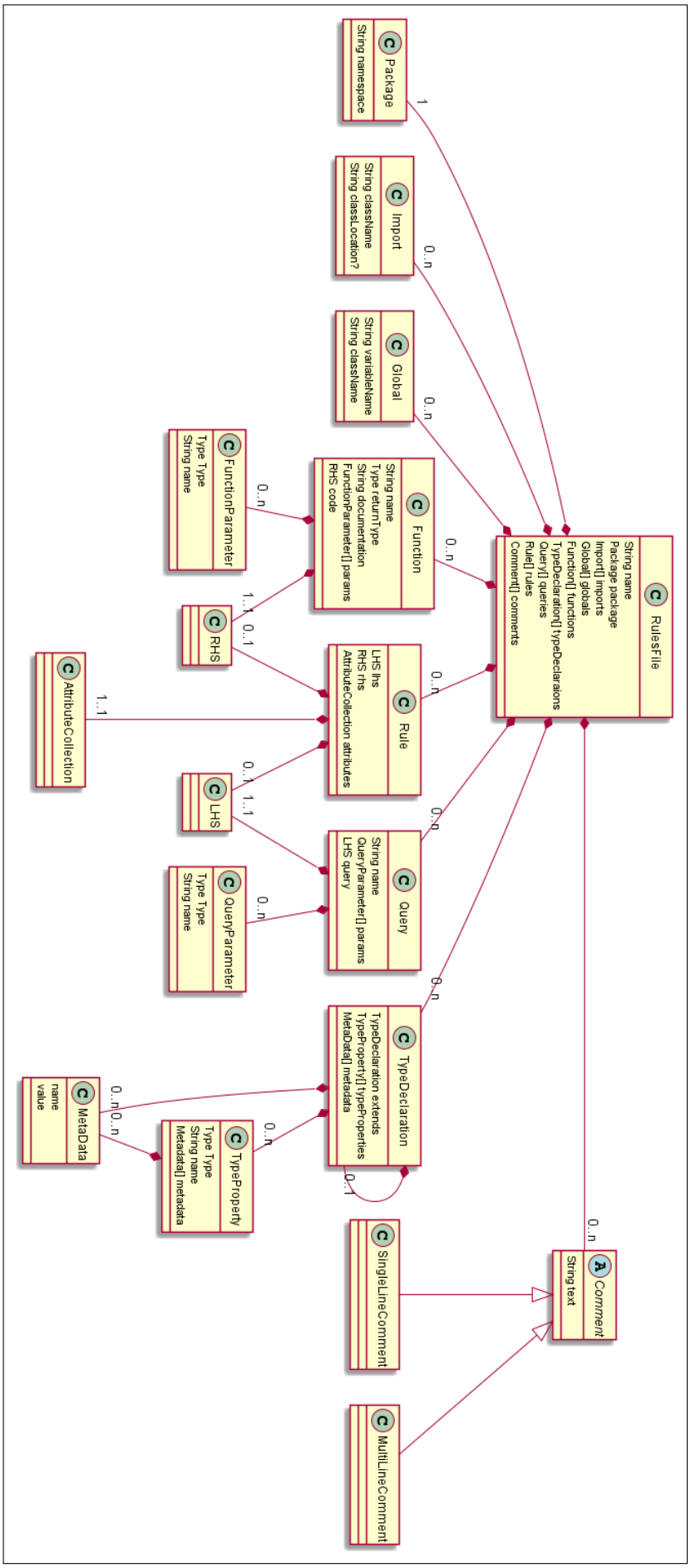


FIGURE F.1: Rule File Concept Hierarchy Diagram

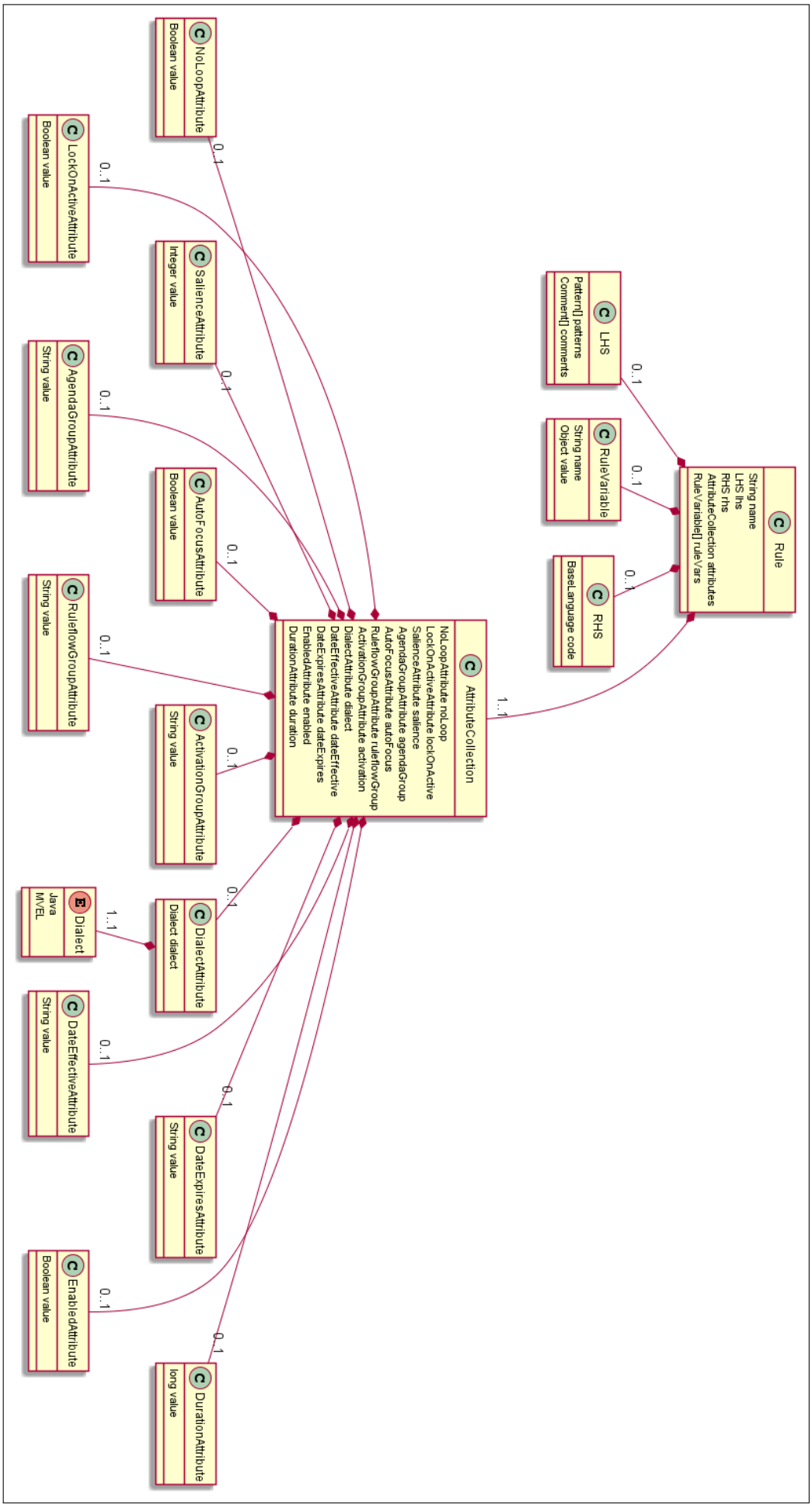


FIGURE F.2: Rules Concept Hierarchy Diagram

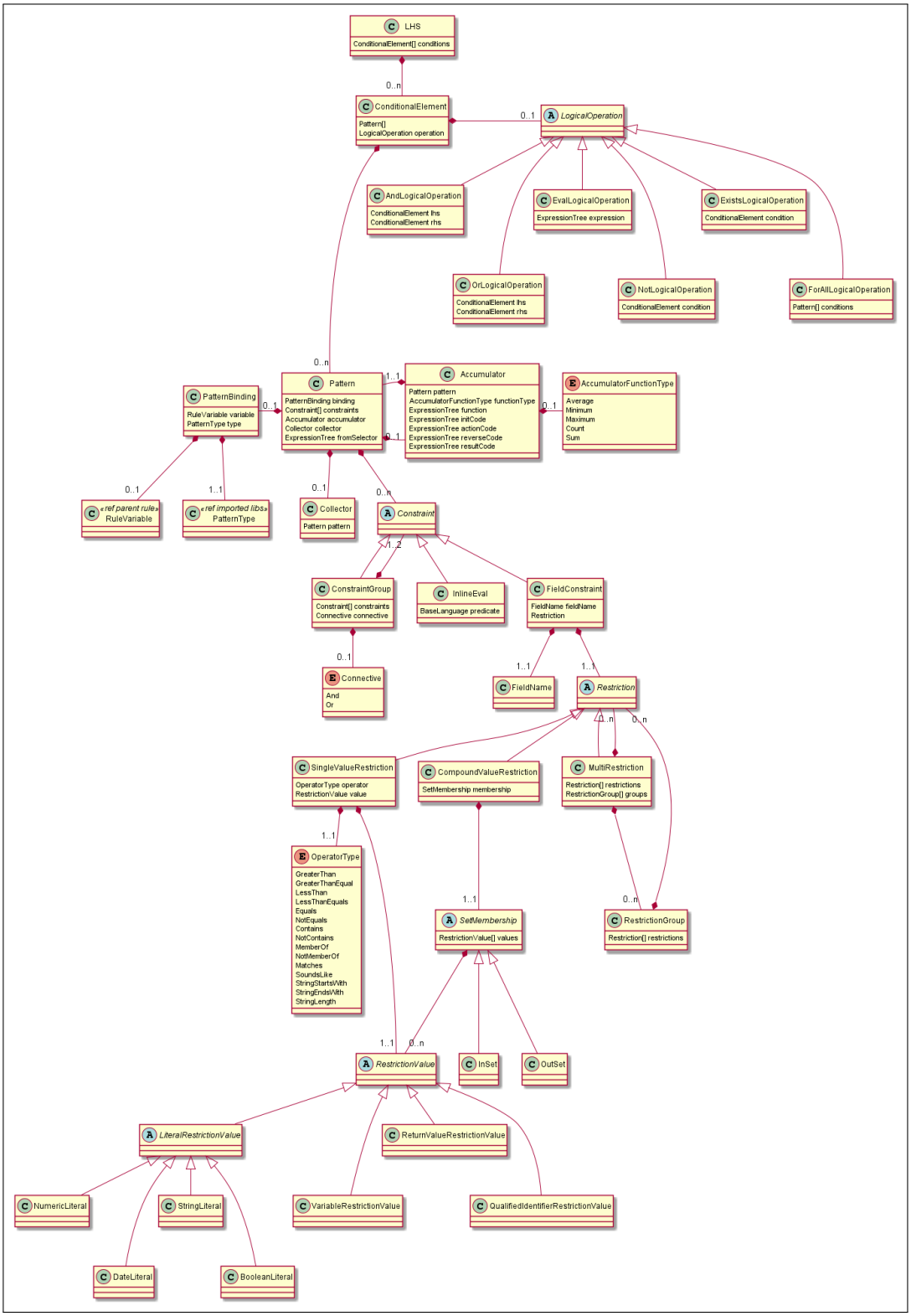


FIGURE F.3: Rule LHS Concept Hierarchy Diagram

Appendix G

Questionnaire Text

Note: This questionnaire was presented on Survey Monkey and thus the text here is a best approximation of their paging system.

G.1 Page 1 - Introduction

Thank you for taking part in this research.

According to Survey Monkey, this survey should take 6 minutes to complete, when we tested it, the average was closer to 10 minutes.

This survey is for the validation section of a research master's project by Paul Spencer at the University of Amsterdam.

The purpose is to determine whether projectional editing can be used to aid the comprehensibility of business rules.

We are using Drools as our example business rules language.

You were selected as you asked or answered a Drools question on StackOverflow, listed Drools as a skill on your LinkedIn profile, or were referred to this survey by someone who previously answered this survey. (please feel free to forward this survey to anyone you know with Drools experience).

It is therefore assumed you are aware of what Drools is.

Projectional editing is a form of writing computer programs directly rather than writing text and having that parsed to create the program. This allows the developer multiple views and editors for the same code.

In this survey, we will present you with a few of these views.

On the following page, there is an animated GIF that will give a small demonstration of what this means.

Figure G.1 shows how this is presented to the subject.

G.2 Page 2 - Example of Projectional editing in Drools

Below is an animated GIF showing an example of a projectional implementation of Drools.

The top section is a tabular projection of the program.

The bottom part is a textual projection of the same program shown at the same time.

In this recording, we are editing in the tabular projection, which automatically updates the textual projection.

Here is placed an animated GIF of a demonstration of our prototype

Question: What is your first reaction to this mode of code editing?

Options: Very positive, Somewhat positive, Neutral, Somewhat negative, Very negative

the order of the options will be randomly presented as either "Very positive" to "Very negative" or "Very nega

Figure G.2 shows how this is presented to the subject.

G.3 Page 3 - Positive about projectional editing

This page is only selected if the user chose very positive or somewhat positive

This question is optional.

you may use the Green "PREV" button to review the previous page.

Question: how would this coding style be useful to your interactions with Drools?

This is an open question with a text box.

Figure G.3 shows how this is presented to the subject.

G.4 Page 4 - negative about projections

This page is only selected if the user chose very positive or somewhat positive

This question is optional.

you may use the Green "PREV" button to review the previous page.

Question: What do you find negative with this style of coding

This is an open question with a text box.

G.5 Page 5 - Testing a projection

In questionnaire version A & D page 5 will be Testing a projection

In questionnaire version B & C page 5 will be Testing textual projection

On this page, we present you with an example projection of a collection of Drools rules, in this case, as a sort of decision table.

We will ask you to describe what you think it does, if you can't that is also good data for us.

A brief description of how this projection works follows:

for the decision table the following text:

1) each row is a rule

2) each column is a fact, or, when indented, a selection criteria of that fact

3) smiley faces indicate that a fact has been selected for a rule

4) if a fact has been selected and a variable is bound to it then the variable name appears instead of the smiley face.

5) the "Then" part of the rule appears in the "Actions" column

for the other table the following text:

1) each row is a rule

2) each column is for a variable or a property of a fact

3) if a property is selected then the selection criteria is in the appropriate cell

4) unselected cells are indicated by a grey/beige color

5) the "Then" part of the rule appears in the "Actions" column

depending on the version of this questionnaire the respondent will see one of the following pictures

Version A - decision table showing rule set 1 (FNWI)

Version B - decision table showing rule set 2 (LAW)

Version C - new table showing rule set 1

Version D - new table showing rule set 2

Question: Please describe what you think this group of rules does

This is an open question with a text box.

Question: How easy or difficult was it to describe this rule set?

Options: Very easy, Somewhat easy, Neutral, Somewhat difficult, Very difficult

the order of the options will be randomly presented as either "Very easy" to "Very difficult" or "Very difficult" to "

Figure G.4 shows how this is presented to the subject.

G.6 Page 6 - Testing textual projection

In questionnaire version A & D page 6 will be Testing textual projection

In questionnaire version B & C page 6 will be Testing a projection

Here we present you a textual projection of Drools rules.

[Note: These are not the same rules as on the previous page]

depending on the version of this questionnaire the respondent will see one of the following pictures

Version A & C - a text projection of rule set 2 (LAW)

Version B & D - a text projection of rule set 1 (FNWI)

Question: Please describe what you think this group of rules does

This is an open question with a text box.

Question: How easy or difficult was it to describe this rule set?

Options: Very easy, Somewhat easy, Neutral, Somewhat difficult, Very difficult

the order of the options will be randomly presented as either "Very easy" to "Very difficult" or "Very difficult

Figure G.5 shows how this is presented to the subject.

G.7 Page 7 - Comparing projections 1

In this question, we ask to compare a new projection to a previously shown projection, on the page named "Testing a projection".

If you wish to reacquaint yourself with the previous projection, you can use the Green "PREV" button at the bottom of this page.

A brief description of how this new projection works follows:

for the decision table the following text:

1) each row is a rule

2) each column is a fact, or, when indented, a selection criteria of that fact

3) smiley faces indicate that a fact has been selected for a rule

4) if a fact has been selected and a variable is bound to it then the variable name appears instead of the smiley face.

5) the "Then" part of the rule appears in the "Actions" column

for the other table the following text:

1) each row is a rule

2) each column is for a variable or a property of a fact

3) if a property is selected then the selection criteria is in the appropriate cell

4) unselected cells are indicated by a grey/beige color

5) the "Then" part of the rule appears in the "Actions" column

depending on the version of this questionnaire the respondent will see one of the following pictures

Version A - new table showing rule set 1

Version B - new table showing rule set 2

Version C - decision table showing rule set 1

Version D - decision table showing rule set 2

Question: How does the above projection compare to the first projection you described?

Options: Much easier to understand, Somewhat easier to understand, Neutral, Somewhat harder to understand, Much harder to understand

the order of the options will be randomly presented as either "Much easier to understand" to "Much harder to ur

Figure G.6 shows how this is presented to the subject.

G.8 Page 8 - Comparing projections 2

In this question, we again ask to compare the new projection, this time to the textual projection, on the page named "Testing textual projection".

If you wish to reacquaint yourself with the textual projection, you can, of course, use the Green "PREV" button at the bottom of this page again.

depending on the version of this questionnaire the respondent will see one of the following pictures

Version A - new table showing rule set 2

Version B - new table showing rule set 1

Version C - decision table showing rule set 2

Version D - decision table showing rule set 1

Question: How does the above projection compare to the first projection you described?

Options: Much easier to understand, Somewhat easier to understand, Neutral, Somewhat harder to understand, Much harder to understand

the order of the options will be randomly presented as either "Much easier to understand" to "Much harder to ur

Figure G.7 shows how this is presented to the subject.

G.9 Page 9 - Single rule helper 1 - Truth table

In questionnaire version A & D page 9 will be the Truth Table

In questionnaire version B & C page 9 will be the Circuit Diagram

Below we present another projection. This is a truth table projection. It highlights the conditions that have to be true for a rule to be selected.

The GIF shows the rule selected and the developer pressing the up and down arrow keys to step through the different true (highlighted in green) and false (highlighted in red) fact selections that result in a true outcome.

An animated GIF of the truth table example

Question: Would this help you with understanding your Drools rules?

Options: It would really help understanding, it would somewhat help understanding, Neutral, It would add a little confusion, It would add a lot of confusion

the order of the options will be randomly presented as either "It would really help understanding" to "It wo

Figure G.8 shows how this is presented to the subject.

G.10 Page 10 - Single rule helper 2 - Circuit Diagram

In questionnaire version A & D page 10 will be the Circuit Diagram

In questionnaire version B & C page 10 will be the Truth Table

This is a circuit diagram of the selection conditions. choosing a different condition highlights how they are related to each other.

The GIF shows the rule selected and the developer pressing the up and down arrow keys to step through the different fact selections (highlighted in yellow) and shown in the circuit diagram, thus showing how the facts relate to each other.

An animated GIF of the Circuit Diagram example

Question: Would this help you with understanding your Drools rules?

Options: It would really help understanding, it would somewhat help understanding, Neutral, It would add a little confusion, It would add a lot of confusion

the order of the options will be randomly presented as either "It would really help understanding" to "It wo

Figure G.9 shows how this is presented to the subject.

G.11 Page 11 - The Statistics page

Here we ask for data that we can use to slice and dice results.

Question: How long was/is your career as a developer?

Options: 0-1 year, 1-3 years, 3-10 years, greater than 10 years, none of the above

Question: When was the last time you had a coding interaction with Drools?

Options: during this week, some time after July 1st 2021, some time after Jan 1st 2021, some time after 2016, some time before 2016

Question: how long did you work with Drools?

Options: for years and intensely, for years but occasionally, not for long but intensely, I barely touched it

Question: Which tools have you used to edit Drools rules?

Checkboxes: Drools workbench, eclipse (with drools plugin), IntelliJ IDEA (with drools plugin), IDE or text editor without Drools assistance, other (please specify) *has textbox*, none of the above

Figure G.10 shows how this is presented to the subject.

G.12 Page 12 - So long, and thanks for all the fish

Thank you for your time. We leave you with a box where you can put in any thoughts about this if you feel like it.

Question: Do you have any thoughts or opinions you would like to share about what you have seen in this questionnaire?

This is an open question with a text box.

Figure G.11 shows how this is presented to the subject.

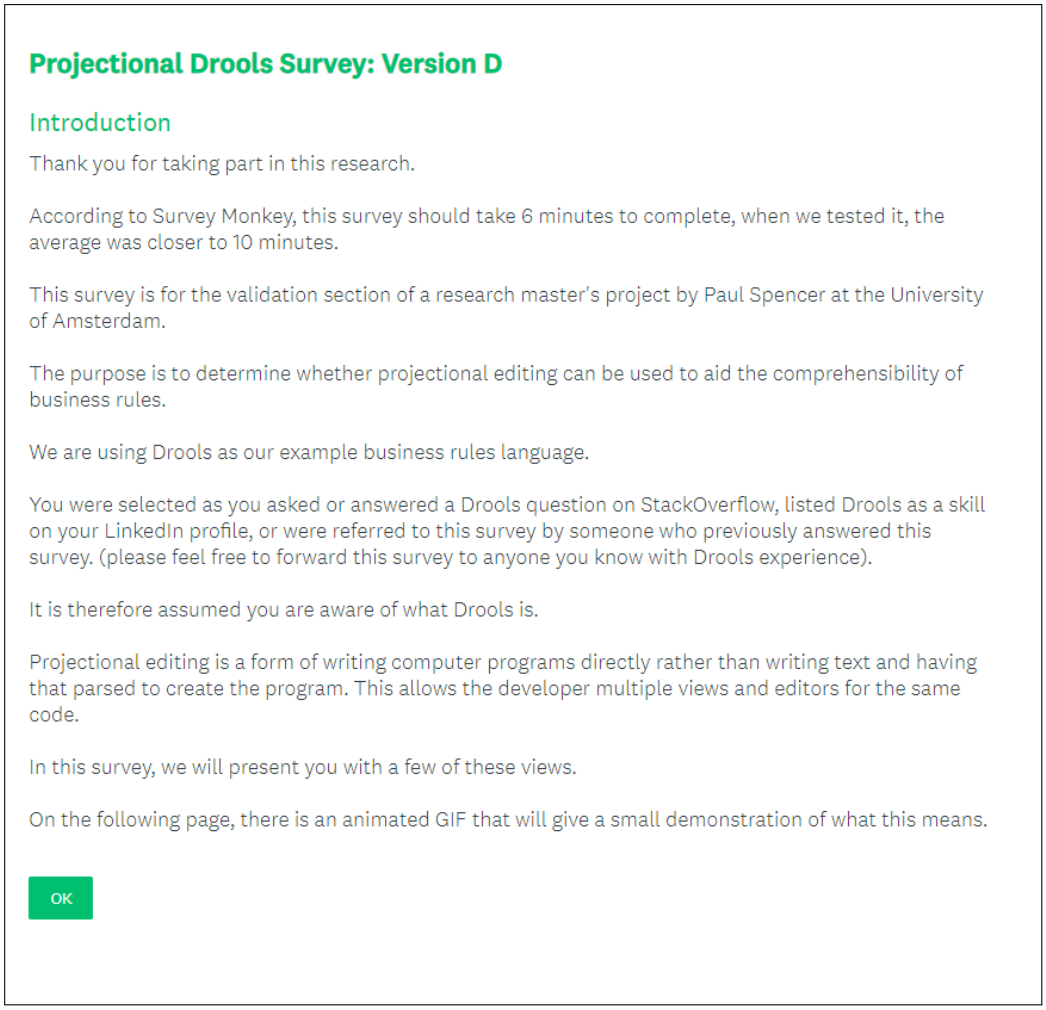


FIGURE G.1: Screen 1 - introduction text

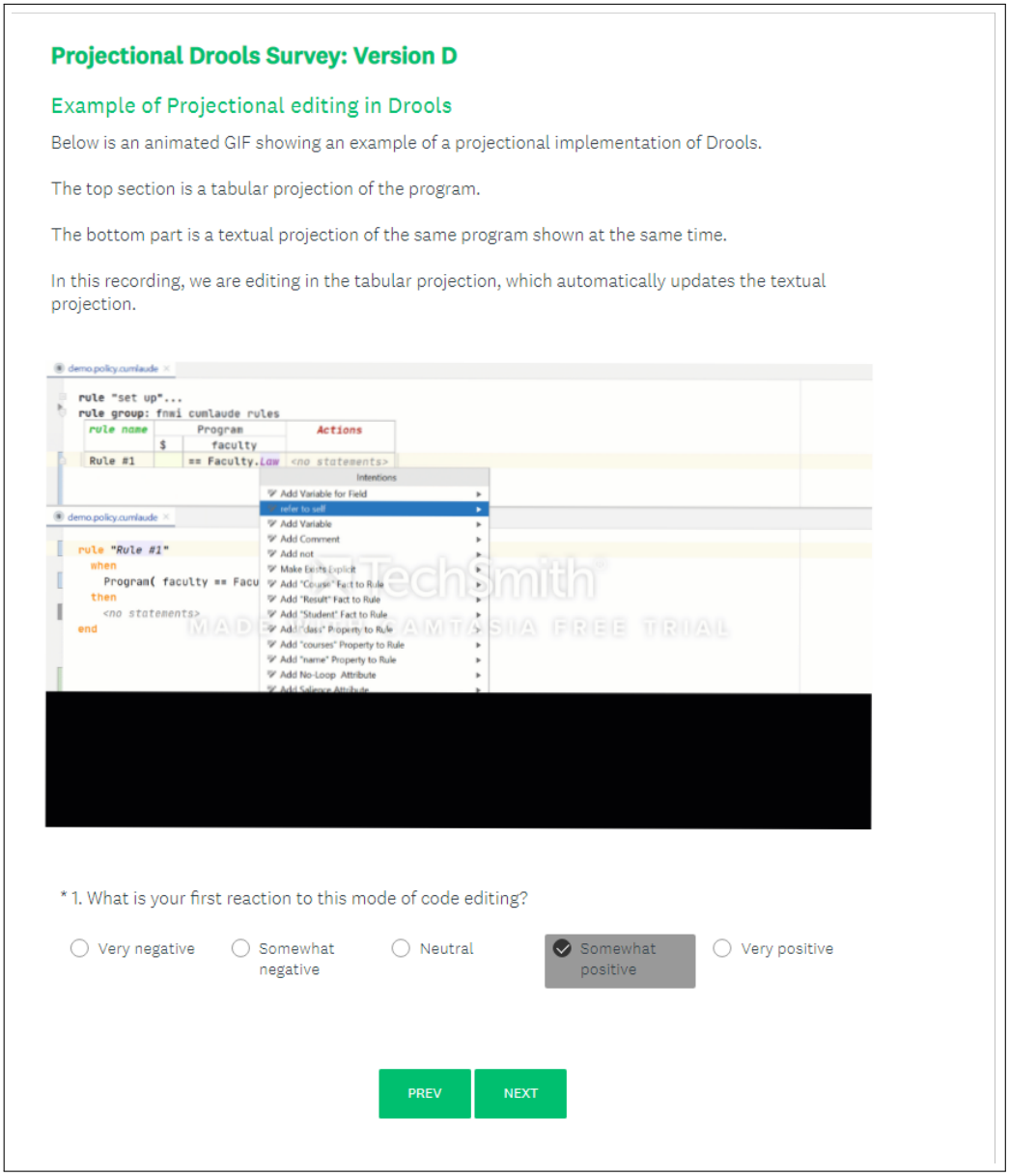


FIGURE G.2: Screen 2 - first impression

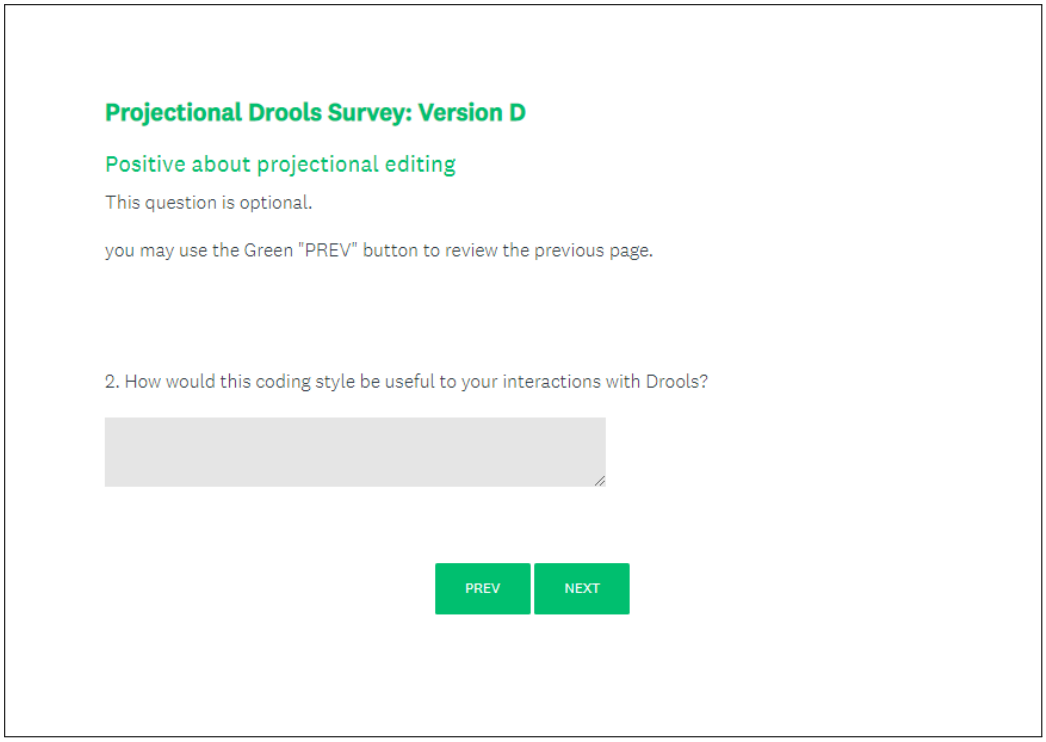


FIGURE G.3: Screen 3 - positive response

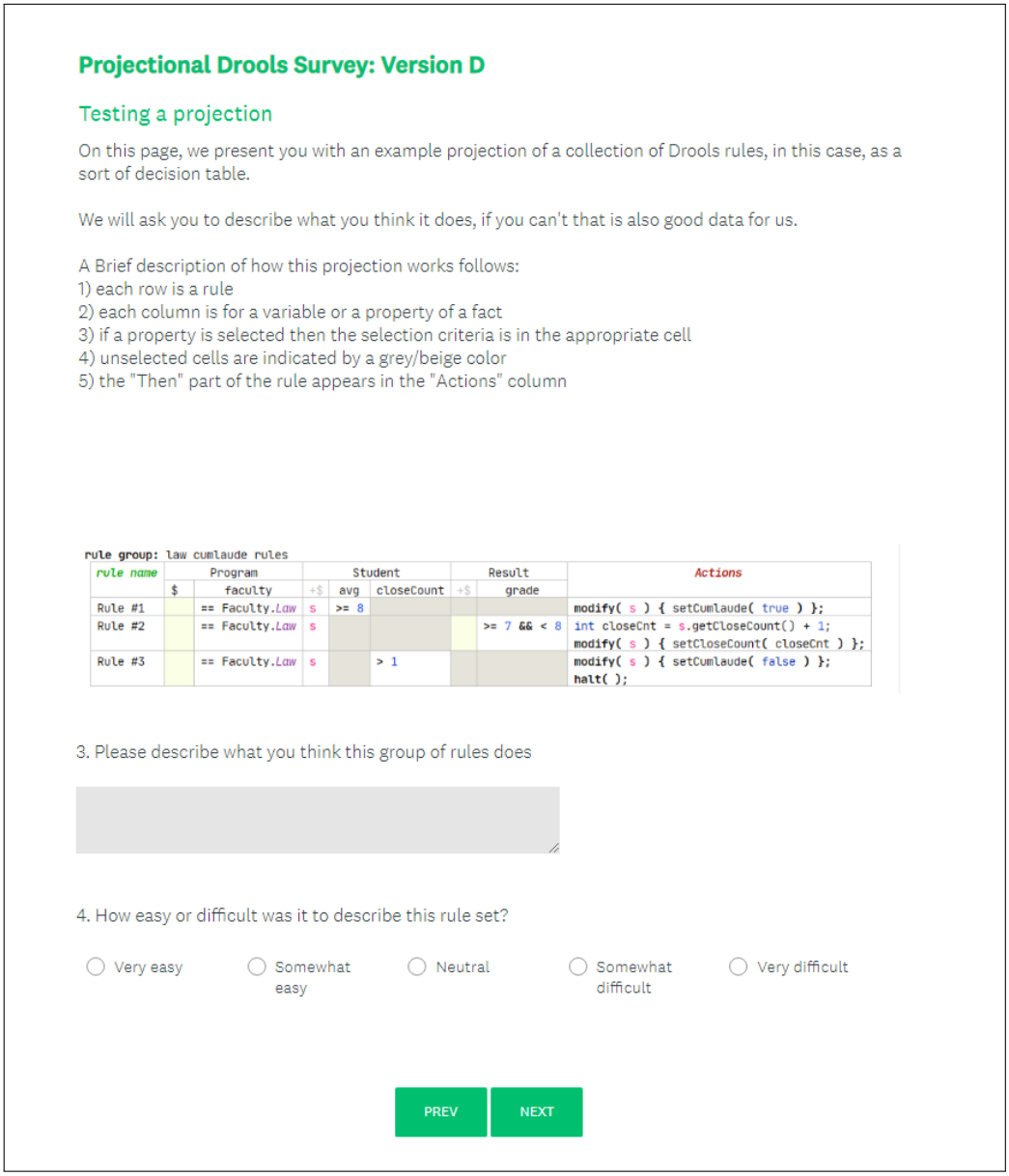
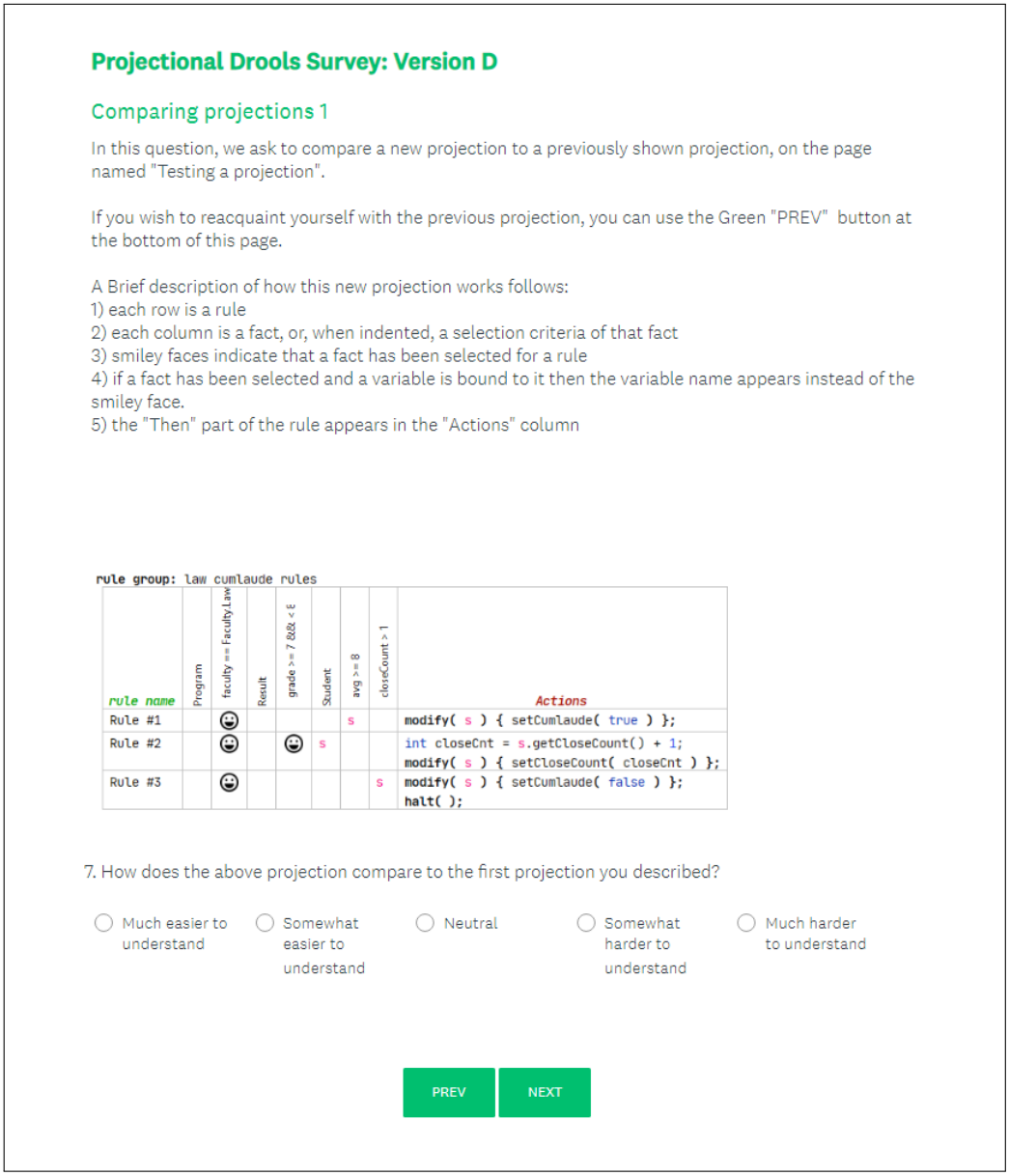


FIGURE G.4: Screen 4 - describe projection

FIGURE G.5: Screen 5 - describe text



Projectional Drools Survey: Version D

Comparing projections 1

In this question, we ask to compare a new projection to a previously shown projection, on the page named "Testing a projection".

If you wish to reacquaint yourself with the previous projection, you can use the Green "PREV" button at the bottom of this page.

A Brief description of how this new projection works follows:
1) each row is a rule
2) each column is a fact, or, when indented, a selection criteria of that fact
3) smiley faces indicate that a fact has been selected for a rule
4) if a fact has been selected and a variable is bound to it then the variable name appears instead of the smiley face.
5) the "Then" part of the rule appears in the "Actions" column

rule group: law cumlaude rules

rule name	Program	faculty == Faculty.Law	Result	grade >= 7 && < 8	Student	avg >= 8	closeCount > 1	Actions
Rule #1		☺				s		modify(s) { setCumlaude(true) };
Rule #2		☺		☺	s			int closeCnt = s.getCloseCount() + 1; modify(s) { setCloseCount(closeCnt) };
Rule #3		☺					s	modify(s) { setCumlaude(false) }; halt( );

7. How does the above projection compare to the first projection you described?

○ Much easier to understand ○ Somewhat easier to understand ○ Neutral ○ Somewhat harder to understand ○ Much harder to understand

PREV NEXT

FIGURE G.6: Screen 6 - compare projections

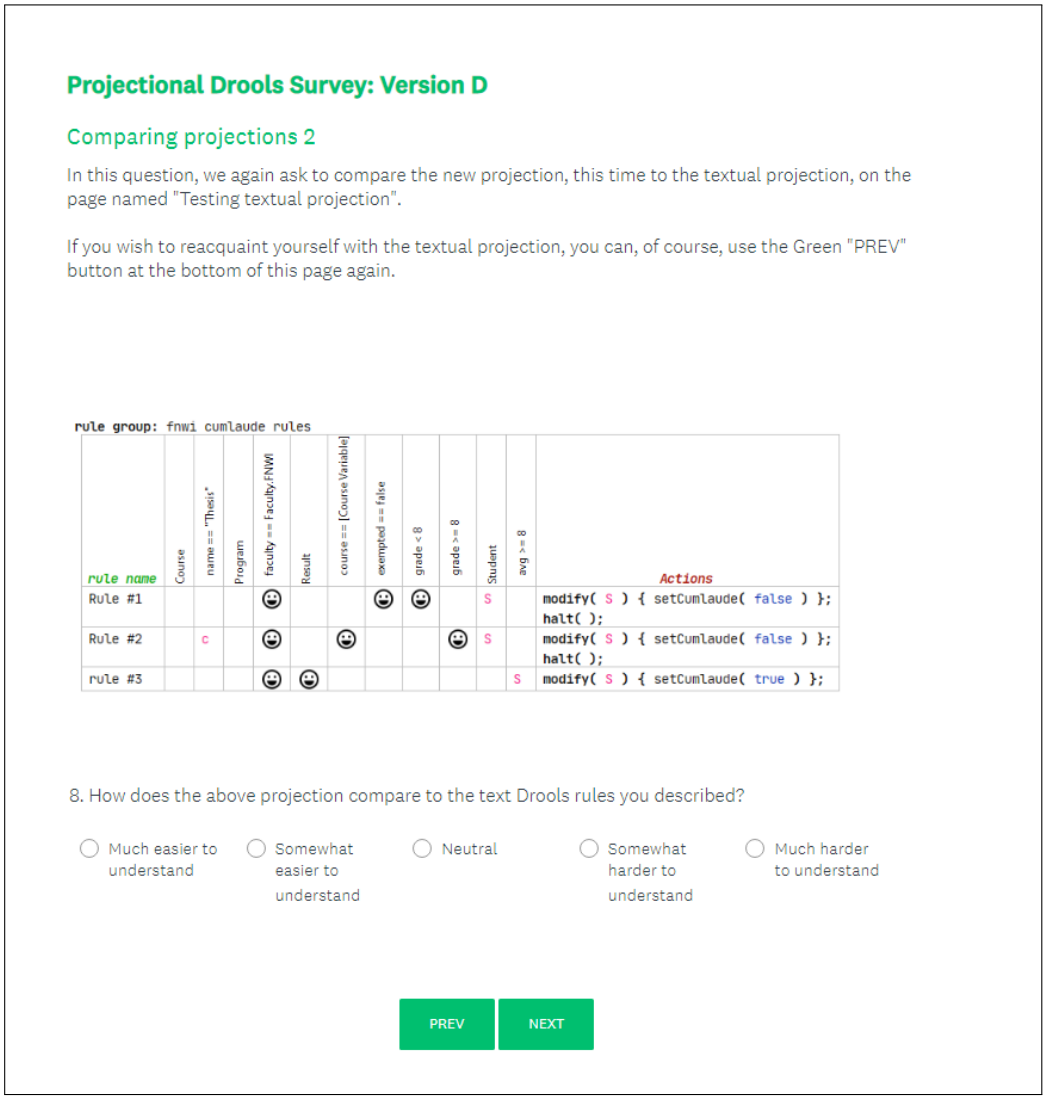


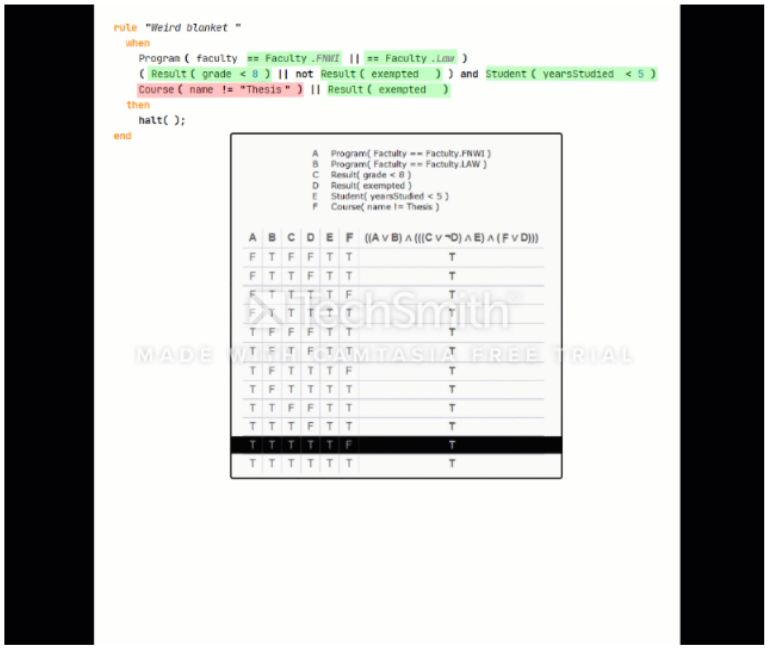
FIGURE G.7: Screen 7 - compare projection to text

Projectional Drools Survey: Version D

Single rule helper 1 - Truth table

Below we present another projection.
This is a truth table projection.
It highlights the conditions that have to be true for a rule to be selected.

The GIF shows the rule selected and the developer pressing the up and down arrow keys to step through the different true (highlighted in green) and false (highlighted in red) fact selections that result in a true outcome.



9. Would this help you with understanding your Drools rules?

- ○ It would really help understanding
- ○ It would somewhat help understanding
- ○ Neutral
- ○ It would add a little confusion
- ○ It would add a lot of confusion

PREV NEXT

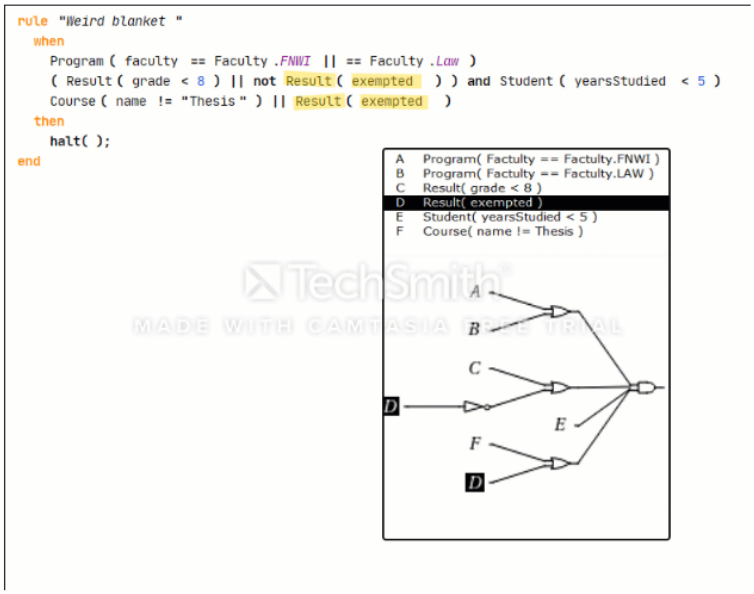
FIGURE G.8: Screen 8 - truth table

Projectional Drools Survey: Version D

Single rule helper 2 - Circuit Diagram

This is a circuit diagram of the selection conditions.
Choosing a different condition highlights how they are related to each other.

The GIF shows the rule selected and the developer pressing the up and down arrow keys to step through the different fact selections (highlighted in yellow) and shown in the circuit diagram, thus showing how the facts relate to each other.



10. Would this help you with understanding your Drools rules?

- It would really help understaning
- it would somewhat help understanding
- Neutral
- It would add a little confusion
- It would add a lot of confusion

PREV NEXT

FIGURE G.9: Screen 9 - circuit diagram

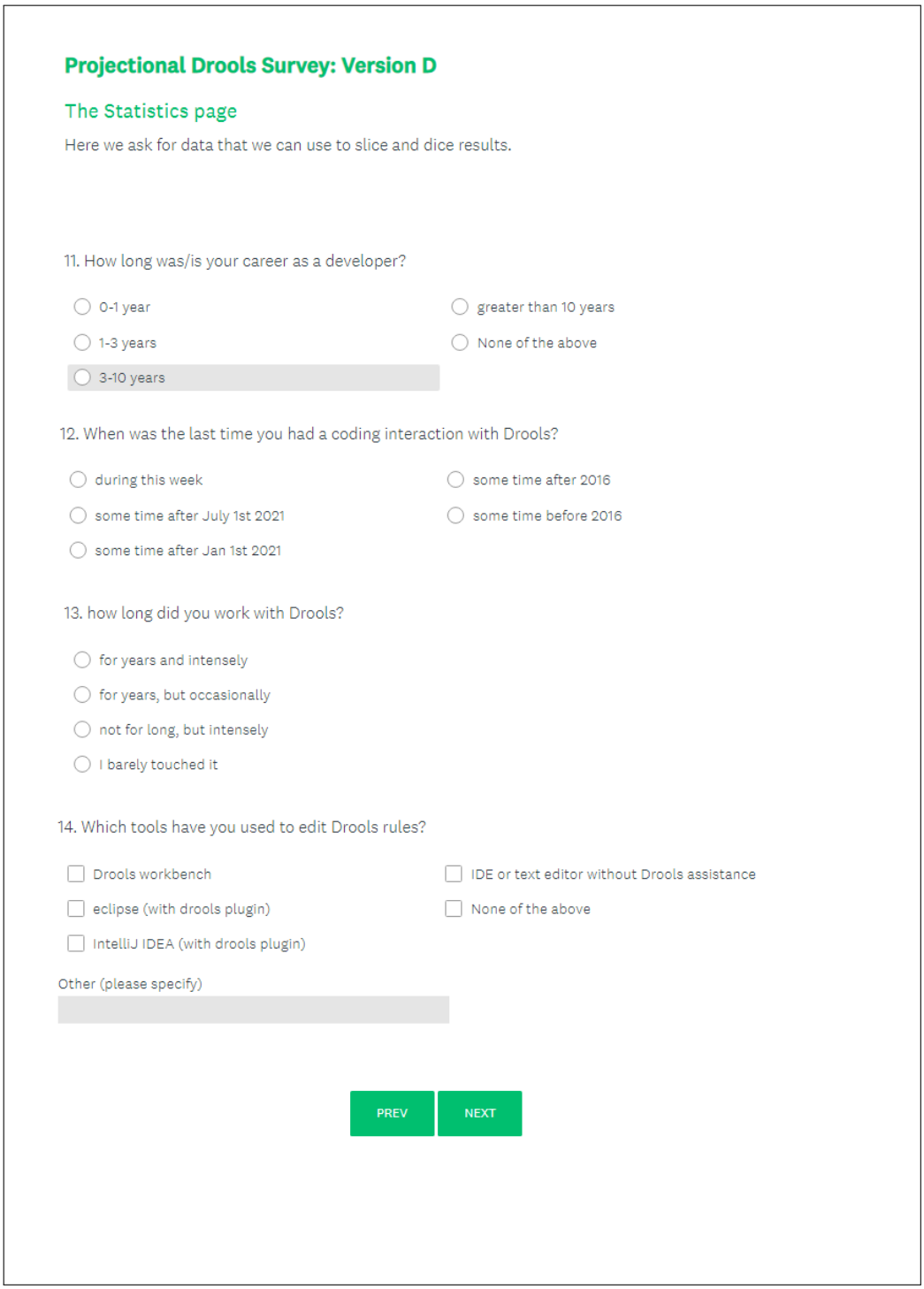


FIGURE G.10: Screen 10 - personal details page

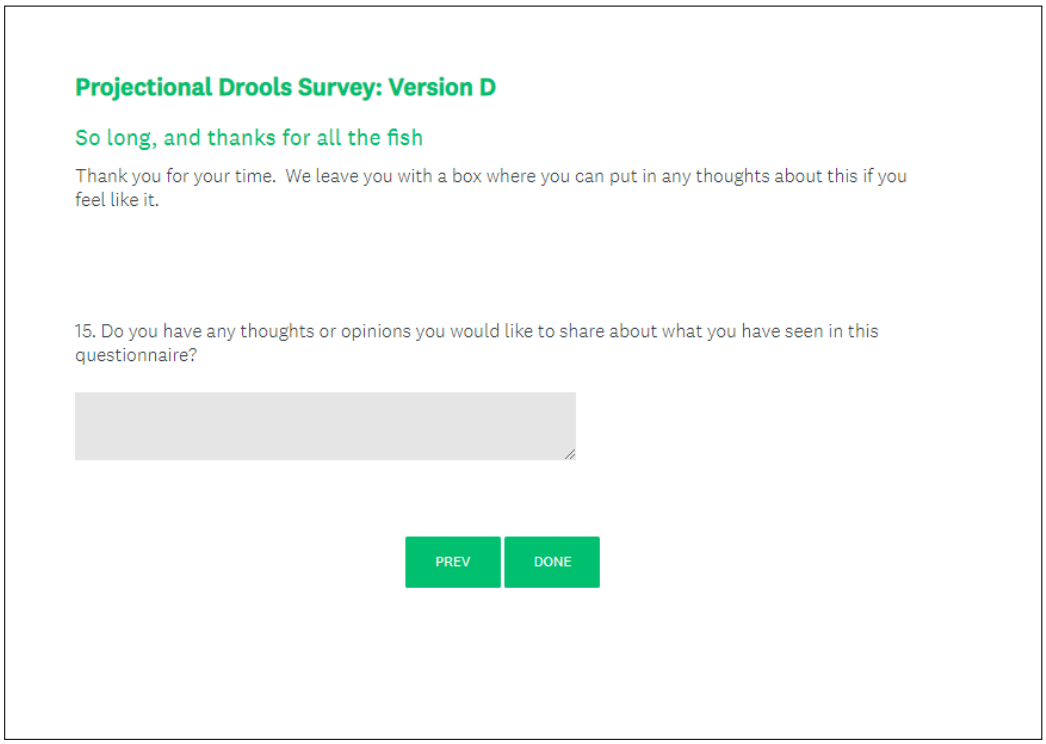


FIGURE G.11: Screen 11 - further comments