UNIVERSITEIT VAN AMSTERDAM

MASTERS PROJECT

Representation Mismatch Reduction for Development in Rules-Based Business Engines

Author:
Paul SPENCER

Supervisor:
Dr. Clemens GRELCK

A thesis submitted in fulfillment of the requirements for the degree of Master of Software Engineering

in the

Graduate School of Informatics
Faculty of Science

August 2, 2021

UNIVERSITY OF AMSTERDAM

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:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. Except for such quotations, this thesis is entirely my work.
- I have acknowledged all of the main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed: ______________________________

Date: ______________________________

UNIVERSITEIT VAN AMSTERDAM

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

Acknowledgements

We would like to acknowledge the School of The Gradate school of Informatics in the Faculty of Science at The University of Amsterdam for their guidance, specifically Dr. Clemens Grelck, who has been a supportive, understanding, and available academic adviser.

We received inspiration from the Strumenta Languages engineering community. Specifically we would like to thank Federico Tomasetti, who shared with me his model of a rules engine in MPS.

Also we would like to thank Václav Pech from JetBrains for the course he created and the time he spent with me explaining MPS. Further, Sergej Koščejev from JetBrains helped us with specific MPS issues during his Office hours.

Other prolific output that terrifically helped our research and development was the Heavy Meta YouTube series from Kolja Dummann and the dozens of papers and books from Markus Voelter, both currently working at Itemis A.G.

[TODO: add mark proctor if he helps out]

Our greatest thanks go out to Toine Khonraad, an alum of this course, who provided me with moral and monetary support, as well as wisdom and friendship that aided in the completion of this, my fourth attempt at getting this project behind me. Without his constant mantra of simplify, simplify, simplify, we would still be implementing the Drools languages now without having made a single projection.

Contents

List of Figures

List of Tables

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.

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 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 3 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 behaviour. 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:

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

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

Rules that represent policies are easily communicated and understood. Rules retain a higher level of independence than conventional programming languages. Rules separate knowledge from its implementation logic. Rules can be changed without changing source code; thus, there is no need to recompile the application's code. Cost of production and maintenance decreases.

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.

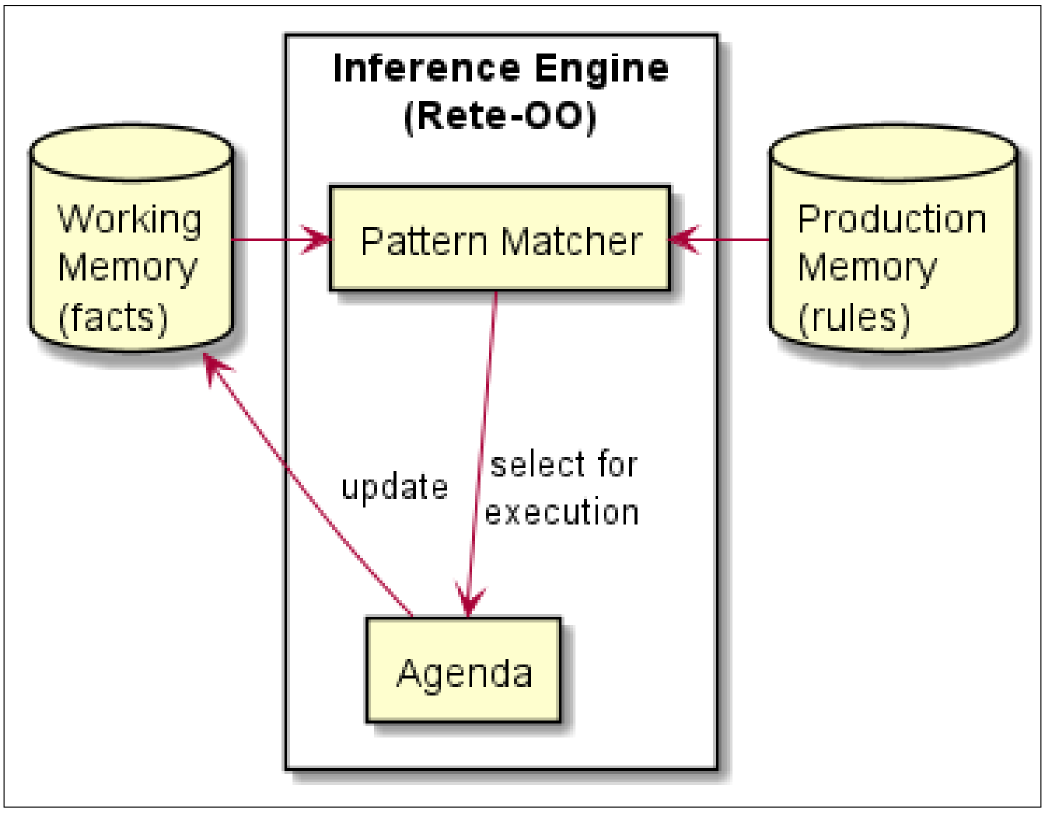


FIGURE 2.1: Drools components.

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.

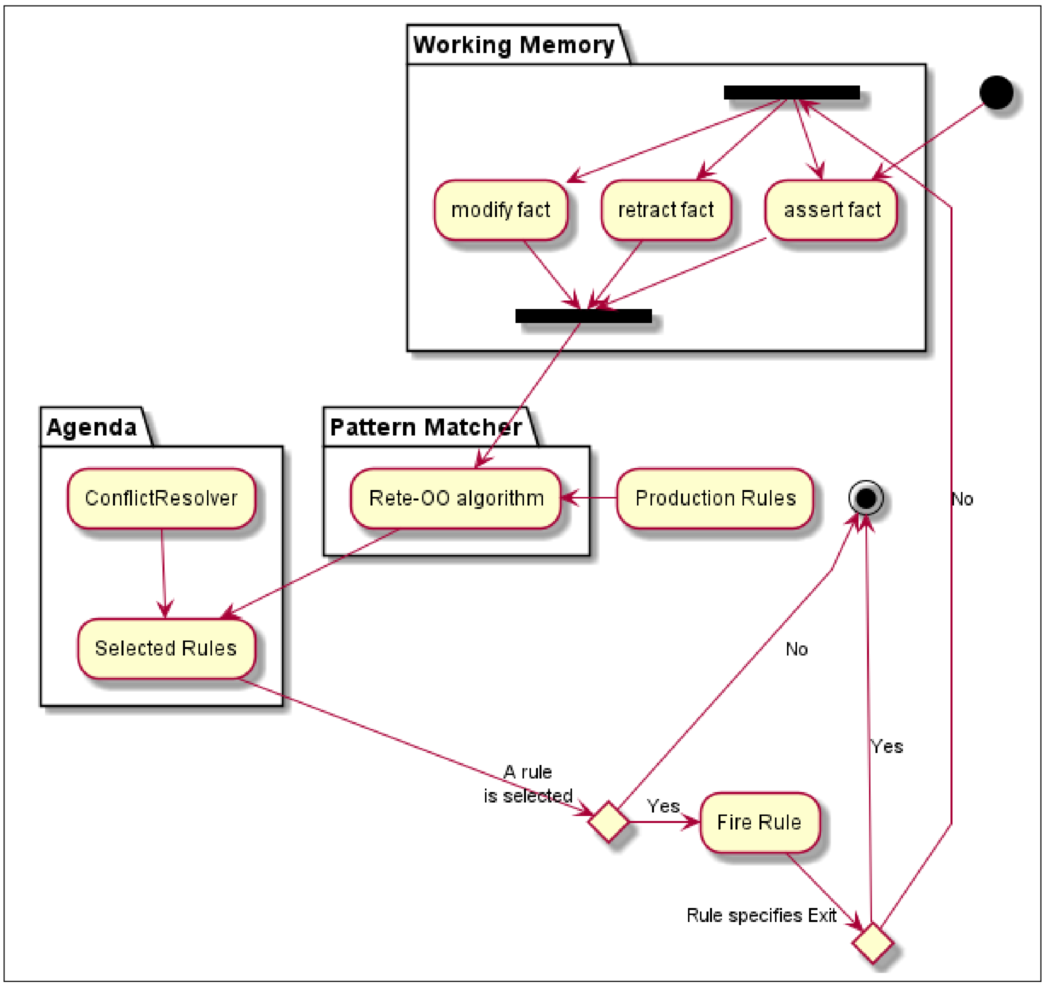


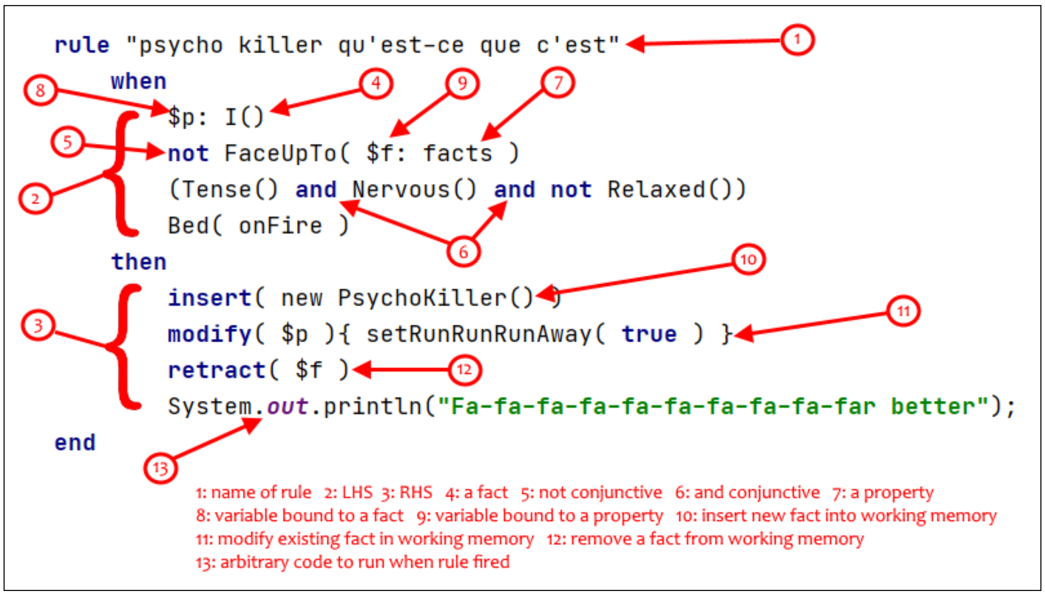
FIGURE 2.2: Drools Inference Loop.

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.



```
rule "psycho killer qu'est-ce que c'est"
    when
        $p: I()
        not FaceUpTo( $f: facts )
        (Tense() and Nervous() and not Relaxed())
        Bed( onFire )
    then
        insert( new PsychoKiller() )
        modify( $p ){ setRunRunRunAway( true ) }
        retract( $f )
        System.out.println("Fa-fa-fa-fa-fa-fa-fa-fa-fa-far better");
end
```

1
8
4
9
7
5
2
6
10
3
11
12
13
1: name of rule 2: LHS 3: RHS 4: a fact 5: not conjunctive 6: and conjunctive 7: a property
8: variable bound to a fact 9: variable bound to a property 10: insert new fact into working memory
11: modify existing fact in working memory 12: remove a fact from working memory
13: arbitrary code to run when rule fired

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.

```
package org.drools.examples.honestpolitician

import org.drools.examples.honestpolitician.Politician;
import org.drools.examples.honest politician.Hope;

rule "We have an honest Politician"
    salience 10
    when
        exists( Politician( honest == true ) )
    then
        insertLogical( new Hope() );
end

rule "Hope Lives"
    salience 10
    when
        exists( Hope() )
    then
        System.out.println("Hurrah!!! Democracy Lives");
end

rule "Hope is Dead"
    when
        not( Hope() )
    then
        System.out.println( "We are all Doomed!!! Democracy is Dead
            " );
end

```

```
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 are basically text editors on steroids. A projectional editor, also known as structured editor or syntax-directed editor, is a different way to write code.

parser based editing

In a traditional, parser-based, development workflow, users use a text editor to represent the program. 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

A projectional editor does not parse any text. In its place, a developer reads and edits 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 be textual. 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.

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 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 behaviours 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.

What advantages does projectional editing bring?

Projectional editing gives advantages both to the language engineer and the program developers. There follows, in no particular order, a number of advantages of projectional editing

Exploratory programming As with their progenitors, syntax-directed editors, modern projectional editors help guide a developer unfamiliar of 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 – Notations are more flexible than ASCII/ANSI/Unicode. Graphical, semi-graphical and textual notations can be mixed and combined. For example, a graphical tool for editing state machines can embed a textual expression language for editing the guard conditions on transitions. Since all editors use the same projectional architecture this works seamlessly. In particular, non-textual notations can be used inside textual notations. Examples include: – mathematical symbols embedded in textual programs – tables that contain text or math symbols – tables embedded in textual programs – mathematical symbols embedded in prose – lines, progress bar other other shapes embedded arbitrarily ProjEs can also mix different notational styles. For example, tables can contain textual expressions and mathematical symbols (as in mbeddr's decision tables), and textual programs can embed graphics.

combination of graphical and textual editing Graphical, semi-graphical and textual notations can be mixed and combined. For example, a graphical tool for editing state machines can embed a textual expression language for editing the guard conditions on transitions.

All notations are built on top of the same editor architecture, so they can be freely mixed (math symbols in tables or text in diagrams) while retaining editor support for all of them.

The projection can take on many forms and it is even possible to combine different types of projections, such as including tables inside a textual presentation. with projectional editing it is natural to combine projections because there is no requirement stating that the syntax should be unambiguous

Multiple views – Since the model is stored independently from its concrete notation, it is possible to represent the same model in different ways simply by providing several projections. Different viewpoints of the overall program can be stored in one model, but editing can still be viewpoint specific. Because the model is stored independent of its concrete notation, it is possible to represent the same model in different ways simply by providing several projections. Different viewpoints [11] of the overall program can be stored in one model, but editing can still be viewpoint specific. Multiple Editors A single concept can define several editors, and a given program can be edited using any of them. unconstrained projection, Change notations on fly

Projectional editing, keeping the code in the AST form, and the absence of parsers, brings along several benefits. • Since the projection is detached from the physical representation of code (AST), authors of languages can define multiple notations and allow the developers to switch between them on the screen. The language author can define multiple alternative visualizations and let the developer choose one that fits best the task at hand.

multiple notations for same language, choose between readability and writability multiple simultaneous views 2) change notations on the fly, so you can choose the notation that best suits the problem at hand Furthermore, the projectional editor is an enabler for multiple notations and for implementing modular and extensible languages. Several alternative (user-switchable) notations for the same program are also possible. Notational diversity is crucial for DSLs targeting non-programmers, such as insurance experts, systems engineers or biologists [32] Because the model is stored independent of its concrete notation, it is possible to represent the same model in different ways simply by providing several projections. Different viewpoints [7] of the overall program can be stored in one model; editing can be viewpoint or aspect specific.

Language composition Its distinguishing feature is its projectional editor, which supports practically unlimited language extension and composition [65] Since projectional editing disambiguates constructs originating from different languages, it does not require the construction of a unifying parser or the definition of composite grammars. Languages can be extended with new constructs and new ways to view and edit them. Since no grammar is used, grammar classes are not relevant, and no syntactic ambiguities can result from the combination of independently developed languages. If two concepts (possibly defined by different language extensions) with the same syntax are valid in the same location, the user is forced to decide which one to instantiate as she enters the program. Since a projectional editor never encounters grammar ambiguities, they can support language composition [9]. ProjEs also avoid the problems with compositionality known from grammar-based systems: ambiguities cannot arise since no grammars are used. In ProjEs, since no grammars are used, language composition is unlimited (discussed systematically in [8])

Projectional editing has two advantages. First, it supports flexible composition of languages because the ambiguities associated with parsers cannot happen in projectional editors. While parser-based systems support language modularization and composition to some degree, it is easy to do and well supported in projectional systems.

Projectional editing, keeping the code in the AST form, and the absence of parsers, brings along several benefits. • Programming languages can be defined in a modular way, and multiple languages can be easily combined together in a single program or one can extend another.

As a consequence of the projectional editor, very few concrete syntax concerns have to be considered when modularizing and composing languages.

no ambiguities,easy language composition, modular languages, embedded languages , extensible languages 3) combine languages easily Projectional code does not have to be parsed, so language syntax can have much more options and languages can be freely combined together. Language composition is easily possible, because languages composition cannot result in ambiguous grammars [1, 19, 20].

projectional editing also supports language composition. because you never run into ambiguities language composition is much more flexible compared to parser based systems.

Projectional editors have two main advantages, both resulting from the absence of parsing. Second, they support various ways of language composition [19], typically including modular language extension as well as embedding of unrelated languages into a host language [44, 51] Language composition refers to using multiple languages in a single program without invasively modifying the definitions of the participating languages.

Extensions can be on arbitrary abstraction levels, thereby integrating modeling and programming and avoiding tool integration issues.

There is no room for ambiguous or conflicting grammars because there is no need for grammars or parsers at all. Since projectional editors never encounter grammar ambiguities, they can support language composition [50]. In contrast to parser-based systems, where disambiguation is performed by the parser after a (potentially) complete program has been entered, in projectional editing, disambiguation happens at the time when the user picks a concept from the code completion menu: if two concepts define the same alias, the user resolves the ambiguity. Furthermore, the projectional editor is an enabler for multiple notations and for implementing modular and extensible languages. Language composition is easily possible, because composed languages cannot result in ambiguous grammars, a significant issue in classical parser-based systems. Before projectional editors, technology was the limiting factor requiring unambiguous grammars.

After a user has picked a language construct and it has been instantiated in the AST, a program is never ambiguous: every node points to its defining concept. This is important, because independently developed languages can be composed in a single program and never lead to structural or syntactic problems, irrespective of the concrete syntax of the participating languages.

For instance, two languages could have overlapping keywords, which parser-based tools could not easily disambiguate (without the need for writing dedicated disambiguation code for the combination of the two languages). Projectional editing has two major advantages: notational diversity and language composability.

IDE functionality The IDE will provide code completion, error checking and syntax highlighting for all languages, even when they are combined. Because projectional languages by definition need an IDE for editing (it has to do the projection!), language definition and extension always implies IDE definition and extension. The IDE will provide code completion, error checking and syntax highlighting for all languages, even when they are combined.

faster code completion as there is a smaller set of valid options , intelligent code completion , low effort to implement mature editor features, syntax highlighting, IDE created by default Since the context is always known, code-suggestions can be used to explore the possibilities that developers have at the current point in the program. The number of selectable concepts is reduced by excluding language components. Also, code-completion is faster when there are less conflicting concept-names. It is a common behavior in projectional editors to use code-suggestions in order to find out which actions or options are valid in the current context. Code-suggestions in projectional editors can reveal possible action and options.

Projectional editor provides intelligent code completion An intelligent code completion can be sophisticated and larger parts of code can be inserted automatically, so syntax can be more explanatory without the need of writing more. The fact that projectional editor manipulates directly with AST allows to implement some editor features that are common in mature IDEs with much less effort. But the projectional approach goes further: when writing the to-be-generated code, the IDE provides syntax coloring, code completion and error checking for the template code. This is extremely hard to do for parsed languages, because the parser of the target language has to be embedded into the template language, and IDE services (code completion, syntax coloring, static checks) would have to be merged as well This aspect is particularly relevant for projectional editors because they usually require users to part from the traditional textual editing experience.

other (language evolution) ease of product line development, no grammar or parser is required, easy to migrating when concrete syntax changes, no need to ”extract” the program structure from a flat textual source, It is also possible to store outof-band data, i.e. annotations on the core model/program. Examples of this include documentation, pointers to requirements (traceability) [8] or feature dependencies in the context of product lines [9]. It is also possible to store out-of-band data, i.e. annotations on the core model/program, such as documentation, pointers to requirements (traceability), or feature dependencies in the context of product lines. The following is a list of benefits of projectional editing: No grammar or parser is required. It is also possible to store out-ofband data, i.e. annotations on the core model/program. Examples of this include documentation, pointers to requirements (traceability) [12] or feature dependencies in the context of product lines [13]. support migrating programs when concrete syntax changes Concrete syntax changes are supported by default with projectional editing without requiring any migration. Since only the AST is stored in the model, all concrete syntax elements purely exist in the editor. In principle, projectional editing is simpler than parsing, since there is no need to ”extract” the program structure from a flat textual source.

Projectional editing gives advantages both to the language engineer and the program developers.

Whilst modern IDE’s will give you quick feedback on existing supported languages, this is not the case for bespoke DSLs.

This idea emerged as early as in 1970s, but it failed to get adopted widely, mostly due to inconvenient and unnatural way of manipulating code.

The freedom in defining the concrete syntax is not problematic for the computer, but it can cause problems for the language user Ambiguous syntax is not only a problem for parsers, but a problem that affects humans as well. but there are also downsides to this syntax ambiguities do not only affect parsers, but humans as well

This notational flexibility leads to drawbacks. In a ParE, a program can always be typed exactly the way it looks by typing the sequence of characters one by one.

ProjE does not support custom layout (SM.6) – the representation is determined completely by the projection rules.

Historically Projectional editors have had useability challenges and weren’t used much in practice.

Traditionally, projectional editors were tedious to use and were hardly adopted in practice.

However, ProjEs have traditionally had two problems. First, for notations that look textual, users expect that the editing behavior resembles classical text editing as much as possible Second, ProjEs cannot store programs in the concrete syntax – otherwise, this syntax would have to be parsed when programs are loaded into the editor. Instead, programs are stored as a serialized AST, often as XML.

However, the challenge in projectional editing is making the editing experience convenient and productive. Traditionally, projectional editors have had a bad reputation because the user experience in editing programs was unacceptable.

Traditionally, projectional editors were hard to use and were not adopted much in practice.

Projectional editing is often considered a drawback because the editors feel somewhat different and the programs are not stored as text, but as a tree (XML).

Traditionally, PEs also have drawbacks, which is why they have not seen much adoption despite their advantages.

The following two drawbacks are the most important. First, for languages that use a textual syntax, users expect the editor to behave like regular, characteroriented text editors. Since PEs do not work with sequences of characters, this can be a challenge.

The second challenge of PEs is infrastructure integration. PEs do not store programs as text, because this would re-introduce parsing and hence negate the advantages. Instead, the AST is persisted, typically as XML. For use in practice, the integration of these XML files with version control systems must be addressed: diff/merge must be supported using the concrete, projected syntax.

Textual source code can be written in any text editor and simply be shared. However, a projection can still be ambiguous or confusing to the user. Some projections are really bad and should be rejected, which this paper advocates.

Thus, it is crucial that projectional editors do not negatively impact editing efficiency for textual notations.

This is their weak spot: for textual notations, projectional editors behave differently from what developers know from traditional text editors in terms of the granularity and restrictions of code edits and code selections.

The main drawback of projectional editors is their questionable usability. Projectional editing can also be used for a syntax that is textual or semi-graphical (mathematical notations for example). However, since the projection looks like text, users expect interaction patterns and gestures known from "real text" to work (such as cursor movements, inserting/deleting characters, rearranging text, selection).

A projectional editor has to "simulate" these interaction patterns to be usable. However, since the projection looks like text, users expect interaction patterns and gestures known from "real text" to work. For a projectional editor to be useful, it has to "simulate" interaction patterns known from real text.

Because projectional languages by definition need an IDE for editing (it has to do the projection!), language definition and extension always implies IDE definition and extension.

As the examples below will show, projectional editing has a number of intriguing advantages, but there is also a price to pay: this price is the additional effort that goes into defining a nicely usable editor.

This transition requires significant training and it can be a cause of resistance. By improving the editing experience we can reduce this risk.

Traditionally, projectional editors have also had disadvantages relative to editor usability and infrastructure integration; those are discussed in [3]. One characteristic of projectional editors is that the language structure strictly determines the structure of the code that can be written in the editor.

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], M´as [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.

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

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.

2.2.2 What are Language Workbenches?

2.2.3 What is MPS?

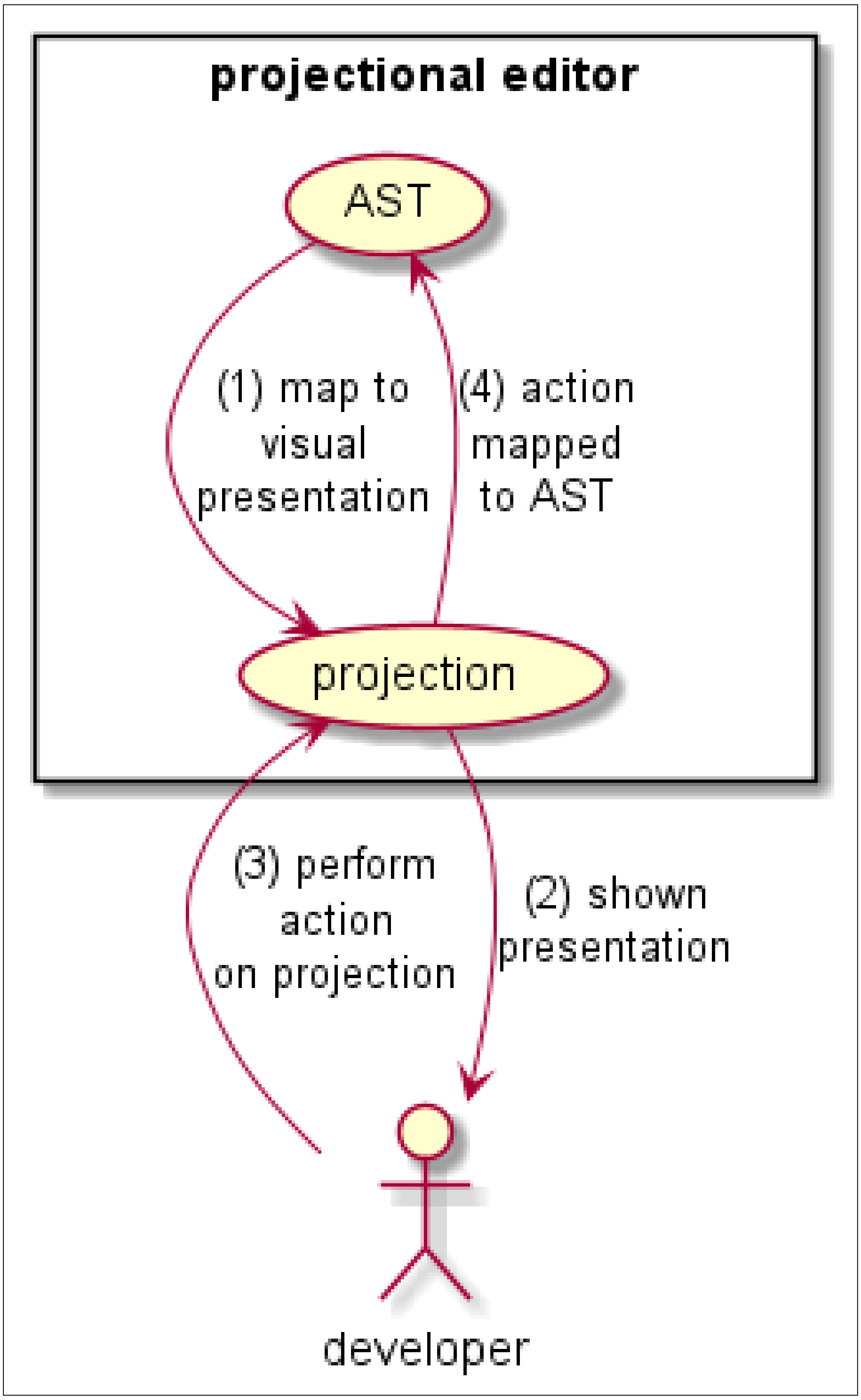


FIGURE 2.4: Projectional editing loop.

Chapter 3

Method

3.0.1 constructing prototypes

We relied on the language Workbench MPS to support our development of a projection of the

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.

Logico-Tractatus Philosophicus
Edsger W. Dijkstra

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]

Appendix A

InterviewTranscripts

Write your appendix content here.

Bibliography

[1] G. A. Miller, "The magical number seven, plus or minus two: Some limits on our capacity for processing information.," *Psychological review*, vol. 63, no. 2, p. 81, 1956.

[2] C. L. Forgy, "Rete: A fast algorithm for the many pattern/many object pattern match problem," in *Readings in Artificial Intelligence and Databases*, Elsevier, 1989, pp. 547–559.

[3] C. J. Date, *What not how: the business rules approach to application development.* Addison-Wesley Professional, 2000.

[4] M. Fowler, *Should i use a rules engine?* `https://martinfowler.com/bliki/RulesEngine.html`, Accessed: 2021-07-18, 2009.

[5] P. Jackson, "Introduction to expert systems," 1986.

[6] E. H. Shortliffe, "Mycin: A rule-based computer program for advising physicians regarding antimicrobial therapy selection.," STANFORD UNIV CALIF DEPT OF COMPUTER SCIENCE, Tech. Rep., 1974.

[7] *CLIPS product page*, `http://www.clipsrules.net/`, Accessed: 2021-07-17.

[8] *Drools product page*, `https://www.drools.org/`, Accessed: 2021-07-17.

[9] *BizTalk product page*, `https://docs.microsoft.com/en-gb/biztalk/`, Accessed: 2021-07-17.

[10] *IBM WebSphere JRules product page*, `https://www.ibm.com/docs/en/iis/11.7?topic=applications-websphere-ilog-jrules`, Accessed: 2021-07-17.

[11] *OpenRules product page*, `https://openrules.com/`, Accessed: 2021-07-17.

[12] D. Sottara, P. Mello, and M. Proctor, "A configurable rete-oo engine for reasoning with different types of imperfect information," *IEEE Transactions on Knowledge and Data Engineering*, vol. 22, no. 11, pp. 1535–1548, 2010.