Directembedding: Concealing the Deep Embedding of DSLs

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Abstract

Authors of embedded domain-specific languages (EDSLs) commonly struggle to find the right balance between the capability and usability of their DSL. On one hand, deeply embedded DSLs give great power to the DSL author but have a steep learning curve for end users. On the other hand, shallowly embedded DSLs are more limiting for the DSL author but offer a more familiar interface to the end users that enables them to quickly become productive with the DSL.

This report presents work on *Directembedding*, a Scala library to implement a thin user-friendly layer on top of an existing deeply embedded DSL[1]. The library accomplishes this using annotations and macros, and requires little to no knowledge of the Scala reflection API. We used Directembedding to implement *slick-direct*, a front-end for the functional relational mapping library *Slick*. Leveraging Directembedding features, slick-direct is able to support a large feature set of Slick in under 300 lines of code.

Contents

1 Introduction

Domain-specific languages (DSLs) provide a simple and high-level way for programmers to accomplish a domain-specific task. DSLs differ from general purpose programming languages in the sense that they enable the programmers to think at a higher level of abstraction at the price of having restricted capabilities. One common use case for DSLs is to enable novice programmers and experts in fields outside of software development to become productive programmers.

[1] Note. This work builds on a previous semester project on the Directembedding library

One method to implement DSLs is to embed them inside a host language. This has the benefit that the DSL can leverage the facilities of the host language. The downside is that an embedded DSL has less flexibility to give arbitrary semantics to a given program. An embedded DSL must obey the host language's syntax and predefined behavior. EDSLs largely fall into two categories:

- *Shallowly embedded DSLs* offer an interface on top of values that are directly provided by the host language. In Scala, these are values such as `Int` and `String`. The benefit of shallow EDSLs is that they have a small learning curve for end users. The interface is familiar to programmers who already have some experience with the host language. The downside to shallow EDSLs is that they are inconvenient for the DSL author. The values in the DSL may have predefined behavior by the host language or third-party libraries. The DSL author must work around these limitations in order to give domain-specific meaning to the programs in her DSL.

- *Deeply embedded DSLs* offer an interface on top of host-language data-structures, which we refer to as an intermediate representation (IR). In Scala, this could be a type such as `Column[Int]` or `Column[String]` for a database DSL. The benefit of deep EDSLs is that they are convenient for the DSL author. The DSL author has full control over the IR, and can therefore give any meaning to programs which invoke operations on the IR. The downside to deep EDSLs is that they can have a steep learning curve for end users. The types in the IR and their behavior may be unfamiliar to the programmers even though they may have some experience with the host language. In a way, deep EDSLs are not too different from ordinary libraries in a general purpose programming language.

There is a clear struggle between DSL users and authors: the users prefer shallow EDSLs while the authors prefer deep EDSLs. Directembedding aims to please both parties. The DSL author can conveniently create her deeply embedded DSL and then use Directembedding to provide a shallow EDSL-like interface for end users.

The main contributions presented in this report are the following:

- Extend previous work on the Directembedding library by adding the possibility to 1) override behavior of predefined and third party types 2) give arbitrary semantics to many standard Scala features 3) configure the reification of DSL programs. Moreover, much work has been put into improving the error messages generated by the library. This work is explained in Section 2.

- Do the first case study on the practical use of the Directembedding library. In under two weeks, we implemented *slick-direct*: a front-end for the `Query` API in the functional relational mapping library Slick. Slick-direct is under 300 lines of code and delegates all implementation logic to the underlying Slick API. Slick-direct supports query operations such as `map`, `flatMap`, `filter`, and `join` with greatly simplified type signatures compared to the lifted embedding in Slick. This work is covered in Section 3.

2 Directembedding

The architecture of the Directembedding library went through a major overhaul in this project. The reification has been extended with new annotations and new capabilities such as language virtualization. The reification is now highly customizable by the DSL author. The library also aims to provide useful error messages where possible.

The following sections explain the improvements that have been made to the Directembedding library in this project. For more details on how Directembedding works please consult the project's Github site[2].

2.1 Architecture

Figure 1 shows the new architecture of Directembedding. PreProcessing is an optional pass in the shallow embedding where the DSL author can transform the program in any way necessary before reification. PreProcessing requires knowledge of the Scala reflection API. The DSLVirtualization pass performs the language virtualization explained in Section 2.2. This pass happens in the shallow embedding. ReificationTransformation is the major component of Directembedding and lifts the shallow embedding into the deep embedding. In this pass, the attached metadata to the shallow embedding is used to reify the program into the DSL author's IR. PostProcessing is an optional pass through the deep embedding where the DSL author can transform the program in any way necessary before the program is passed back to the user.

The entry point to using Directembedding is now `DETransformer`. The design of the DETransformer is inspired by the `YYTransformer` in Yin-Yang [1]. An example Directembedding DSL is provided the `example` package object.

2.2 Language virtualization

Language virtualization is the process of converting standard language features into method calls, in order to give them arbitrary semantics. Such

[2] https://github.com/directembedding/directembedding

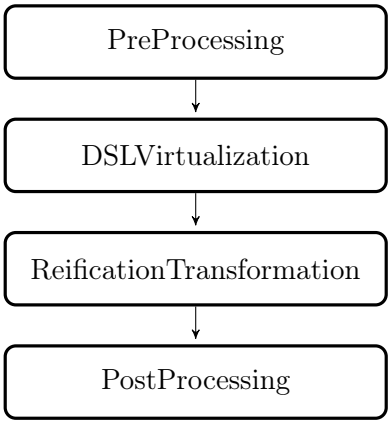

Figure 1: The Directembedding transformation pipeline.

language features include if-then-else statements, loops, and variable assignments. It is not possible to override the semantics of such statements in Scala without macros.

Directembedding uses the language virtualization provided by the Yin-Yang [1] framework. This transformation happens in the DSLVirtualization pass. The DSL author is able to configure which language features to override through the `DslConfig` trait. The `LanguageVirtualizationSpec` shows 43 examples of how to use the language virtualization feature in Directembedding.

2.3 Overriding predefined and third-party types

Directembedding supports the ability to override the behavior of predefined and third-party types. Predefined types are types provided by standard Scala libraries, such as `Int` and `String`. Third-party types can be any types in a third-party library supported by the DSL.

Reification for overriden types works the same way as reification with any other types. The `typeMap` argument to `DETransformer` tells Directembedding where to to look for reification annotations. If Directembedding does not find metadata to an invoked symbol, Directembedding will look for annotations on types in the `typeMap`. This search on types and finding matching symbols is currently implemented in a naïve way, and could be improved in future implementations. `TypeOverridingSpec` provides 6 examples of how to use the type overriding feature in Directembedding.

2.4 Configurable reification

2.5 Improved error messages

- Explain `reifyAs` annotations, provide examples.

- Explain pipeline.

3 Case study: slick-direct

- Compare type signatures in `slick.direct` and `slick.lifted`, see below.

```
1  // slick.lifted
2  def map[F, G, T](f: E => F)
3    (implicit shape: Shape[_ <: FlatShapeLevel, F, T, G]): Query[G, T, C]
4  // slick.direct
5  def map[F](f: E => F): Query[F, C]
```

```
1  // slick.lifted
2  def filter[T <: Rep[_]](f: E => T)(implicit wt: CanBeQueryCondition[T]): Query[E, U, C]
3  // slick.direct
4  def map[U](f: T => U): Query[U, C]
```

```
1  // slick.lifted
2  def joinFull[E1 >: E, E2, U2, D[_], O1, U1, O2](q2: Query[E2, _, D])
3    (implicit ol1: OptionLift[E1, O1],
4              sh1: Shape[FlatShapeLevel, O1, U1, _],
5              ol2: OptionLift[E2, O2],
6              sh2: Shape[FlatShapeLevel, O2, U2, _]): BaseJoinQuery[O1, O2, U1, U2, C, E1, E2]
7  // slick.direct
8  def joinFull[T2, D[_]](q: Query[T2, D]): BaseJoinQuery[Option[T], Option[T2], T, T2, C]
```

4 Related work

Yin-Yang.

5 Future research

- Complete slick-direct, an opinionated front-end for slick. Features include: custom types for primary keys and encrypted strings, customizable type provider, and implement remaining API.
- Explore alternative uses of directembedding.

References

[1] Vojin Jovanovic et al. "Yin-yang: concealing the deep embedding of DSLs". In: *Proceedings of the 2014 International Conference on Generative Programming: Concepts and Experiences-GPCE 2014*. ACM Press, 2014, pp. 73–82. URL: http://infoscience.epfl.ch/record/203432 (visited on 02/16/2015).