Yin-Yang: Concealing the Deep Embedding of DSLs

Demonstration: a DSL for in-memory querying

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Abstract. Deeply embedded domain-specific languages (EDSLs) inherently compromise programmer experience for improved program performance. Shallow EDSLs complement them by trading program performance for good programmer experience. We present Yin-Yang, a framework for DSL embedding that uses Scala reflection to reliably translate shallow EDSL programs to their corresponding deep EDSL programs. This automatic *translation* allows program prototyping and debugging in the user friendly shallow embedding, while the corresponding deep embedding is used in production—where performance is important. The reliability of the translation completely conceals the deep embedding from the DSL user. For the DSL author, Yin-Yang generates deep DSL embeddings from their shallow counterparts by reusing the program translation. This obviates the need for code duplication and assures that the implementations of the two embeddings are always synchronized.

Keywords: Embedded Domain-Specific Languages, Macros, Deep Embedding, Shallow Embedding, Compile-Time Meta-Programming

1 Introduction

External domain-specific languages (DSLs) are languages with a custom compiler specialized to a particular application domain. Knowledge about the domain and specialization of the language give the compiler possibilities for optimization that do not exist in *general-purpose languages*. This often leads to execution times close to hand-optimized programs [3]. A restricted language makes it easier for *DSL users* to learn the language.

The development of external DSLs includes building a parser and a type checker as well as a large tool-chain (i.e., debuggers, IDEs, and documentation tools). An appealing alternative are *embedded DSLs* (EDSLs) [2] that reuse the parser, the type checker, and the tool-chain of a general-purpose host language to minimize required development effort. We can classify DSL embeddings into:

- *Shallow embeddings.* Values in the embedded language are *directly* represented by the values in the host language. A special sub-category of shallow

embeddings are *direct embeddings* where language constructs and term types are exactly the same as in the host language.

– *Deep embeddings.* Values in the embedded language are symbolically (with data structures) represented in the host language.

Direct embeddings are typically friendly for the DSL user as they *i) linguistically match* the host language and *ii)* can be easily debugged since values of the embedded language directly correspond to the values of the host language. However, since the structure of the programs is not completely known, the number of possible domain-specific optimizations is limited.

Deep embeddings reify the DSL programs into an *intermediate representation* (IR). This reification hinders usability as it often relies on complex type system constructs that create a linguistic mismatch with the host language. Furthermore, the IR construction in the programs disallows value inspection with classical debuggers and makes debugging hard. However, the IR being domain specific opens new opportunities for optimization and allows good execution times.

The main idea of Yin-Yang is to use *reflection* to translate programs written in an unmodified direct embedding into their deeply embedded counterparts. Since the fundamental difference between the interfaces of the two embeddings is in their types, we propose a generic translation between the two embeddings that is configurable with a separate *type translation.*

The translation forms the core of Yin-Yang, a generic framework for DSL embedding, that uses Scala's macros [1] to reliably translate direct EDSL programs into the corresponding deep EDSL programs. The virtues of the direct embedding are used during program development when performance is not important. The translation is then applied when performance is essential or alternative interpretations of a program are required. In effect, the translation completely conceals the deep embedding from the user.

To avoid error prone maintenance of synchronized, direct and deep, embeddings Yin-Yang reuses the core translation to generate the deep embeddings based on the definition of direct embeddings. Since the same translation is applied both for the EDSL definition and the EDSL program, the equivalence between the embeddings is assured. With deep embedding generation DSL author can focus on the domain-specific optimizations while the interface is completely handled by Yin-Yang.

2 Demonstration: A DSL for In-Memory Queries

Our demonstration shows how Yin-Yang is used by: *i)* a DSL author and *ii)* a DSL user. The DSL author only needs to define the direct embedding of a DSL and declare domain-specific program transformations. The DSL user writes code in the user friendly shallow embedding and can be agnostic about the deep embedding. For the purpose of the demonstration we use a DSL for writing in-memory queries. The demonstration proceeds as follows:

```
class SelectOp[A](parent: Oper[A])         def transform(s: Sym[Any]): Exp[Any] = s match {
  (pred: A => Boolean) extends Oper[A]{       case SelectOp(SelectOp(r)(pred1))(pred2) =>
  def open() = parent.open                      SelectOp(r)(x => pred1(x) && pred2(x))
  def next() = parent findFirst pred          case _ => super.transform(s)
  def reset() = parent.reset                 }
  def close() = ()
}
```

Fig. 1: A selection query operator (left) and domain-specific transformation rules (right).

DSL author: Writes a naïve Scala implementation of common query operators. An example operator is presented in Figure 1 on the left.

DSL user: Can immediately write concise queries in the DSL. Although the query performance is satisfactory for prototyping, in production, the overhead is unacceptably large.

DSL author: To improve on the situation the author decides to provide a deep embedding for the query engine. All he needs to do is place a single Scala class annotation per query operator he implemented. The annotation marks that the deep embedding will be generated. Yin-Yang then processes the annotated classes and generates the deep embedding that includes reification logic and code generation.

DSL user: Places queries he wrote in a DSL scope that activates the deep embedding. After putting queries into the DSL scopes the user is still faced with the same type errors as before and program execution errors can still be debugged in a standard debugger. In production, however, the DSL scope will invoke the translation and apply all standard compiler optimizations to the DSL yielding significant performance improvements.

DSL author: Decides to further improve performance by introducing the domain specific optimizations in the query language. The DSL author declares simple rewrite rules that the DSL compiler will later apply. The rewrite rules are specified through Scala pattern matching. The rules for selection elimination are shown in Figure 1 on the right.

DSL user: Measures performance of his DSL and realizes that the generated code performs on par with the hand-optimized version of the query.

References

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