Modern type-safe embedding of attribute grammars

An exercise with functional zippers in Haskell

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Abstract. Attribute grammars are a powerful, declarative formalism to implement and reason about programs which, by design, are conveniently modular.
Although a full attribute grammar compiler can be tailored to specific needs, its implementation is highly non trivial, and its long term maintenance is a major endeavor.
In fact, maintaining a traditional attribute grammar system is such a hard effort that most such systems that were proposed in the past are no longer active.
Our approach to implement attribute grammars is to write them as first class citizens of a modern functional programming language.
We improve a previous zipped-based attribute grammar embedding making it non-intrusive (i.e. no changes need to be made to the user-defined data types) and type-safe. On top of that, we achieve clearer syntax by using modern Haskell extensions.
We believe our embedding can be employed in practice to implement elegant, efficient and modular solutions to real life programming challenges.

Keywords: Embedded Domain Specific Languages · Zipper data structure · Memoization · Attribute Grammars · Higher-Order Attribute Grammars · Functional Programming

1 Introduction

Attribute Grammars (AGs) are a declarative formalism that was proposed by Knuth [7] in the late 60s and allows the implementation and reasoning about programs in a modular and convenient way. A concrete AG relies on a context-free grammar to define the syntax of a language, and on attributes associated to the productions of the grammar to define the semantics of that language. AGs have been used in practice to specify real programming languages, like for example Haskell [2], as well as powerful pretty printing algorithms [16], deforestation techniques [4] and powerful type systems [11].

When programming with AGs, modularity is achieved due to the possibility of defining and using different aspects of computations as separate attributes. Attributes are distinct computation units, typically quite simple and modular, that can be combined into elaborated solutions to complex programming problems. They can also be analyzed, debugged and maintained independently which eases program development and evolution.

AGs have proven to be particularly useful to specify computations over trees: given one tree, several AG systems such as [14, 3, 8, 17] take specifications of which values, or attributes, need to be computed on the tree and perform these computations. The design and coding efforts put into the creation, improvement and maintenance of these AG systems, however, is tremendous, which often is an obstacle to achieving the success they deserve.

An increasingly popular alternative approach to the use of AGs relies on embedding them as first class citizens of general purpose programming languages [12, 9, 13, 15, 18, 1]. This avoids the burden of implementing a totally new language and associated system by hosting it in state-of-the-art programming languages. Following this approach one then exploits the modern constructions and infrastructure that are already provided by those languages and focuses on the particularities of the domain specific language being developed.

Functional zipper [6] is a powerful abstraction which greatly simplifies the implementation of traversal algorithms performing a lot of local updates. Functional zippers have successfully been applied to constuct an attribute grammar embedding in Haskell [9, 10]. Despite its elegance, this solution had a major drawback which prevented its use in real-world applications: attributes were not cached, but rather repeatedly recomputed which severely hurt performance. Recently, this flaw has been eliminated [5] and replaced with a different one: the approach became intrusive, i.e. to benefit from the embedding user-defined data structures have to be adjusted.

In this paper we present an alternative mechanism to cache attributes based on a self-organising infinite grid. This graph is laid on top of the user-defined algebraic data type and mirrors its structure. The used-defined data type remains untouched. The embedding is then based on two coherent zippers (rather than one) traversing the data structures in parallel. On top of being non-intrusive our solution is completely type-safe. Modern Haskell extensions such as `ConstraintKinds` allow us to propagate constraints down in the ADT completely eliminating runtime type casts present in the previous versions. Another side benefit of using modern Haskell is a cleaner syntax with less code being generated with Template Haskell.

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