LETTER

Removing Qualified Names in Modular Languages

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SUMMARY Although the notion of qualified names is popular in module systems, it causes severe complications. In this paper, we propose an alternative to qualified names. The key idea is to import the declarations in other modules to the current module before they are used. In this way, all the declarations can be accessed locally. However, this approach is not efficient in memory usage. Our contribution is the module weakening scheme which allows us to import the minimal parts. As an example of this approach, we propose a module system for functional languages.

key words: modules, qualified names.

1. Introduction

Modularity is the key technique for dealing with large programs. Most modern languages (including object-oriented ones) employ qualified names of the form \( m.f \) to access a method \( f \) in a module \( m \). Although the notion of qualified names is simple to implement, it leads to unnecessarily long names and it runs counter to the notion of qualified names. This problem should be eliminated to preserve conciseness. The core of knowledgebase representation, i.e., the concise notion of qualified names is easy to implement, it leads to unnecessarily long names and it runs counter to the notion of qualified names.

The former one has the following semantics: the declarations of a module. As an example of this approach, we propose a module system for functional languages.

The latter one has the following semantics: first evaluate \( f(t_1, \ldots, t_n) \) w.r.t. \( /m \) and set \( V \) to the resulting value \( w \). This expression thus supports the idea of importing all the declarations of a module.

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The latter one has the following semantics: first evaluate \( f(t_1, \ldots, t_n) \) w.r.t. \( /m \) and set \( V \) to the resulting value \( w \). This expression thus supports the idea of importing some (logical consequence of) declarations of a module. This is called module weakening/module customizaton. Note that the notion of MQ declarations is a novel feature which is not present in traditional languages. For example, \( (fib(3) = V)^{m}f \) is a querying declaration where the value of \( v \) is not known. Its value is later determined by evaluating \( fib(3) \) w.r.t. the “fibonacci” module \( m.f \).

Although our approach can be applied to other programming paradigms, this paper focus on functional languages. That is, we extend a functional language with MI/MQ declarations.

2. A Case Study: Functional Languages

The theory of recursive functions, which we call \( REC \), provides a basis for functional programming. It includes operations of composition, recursion, etc. Although \( REC \) is quite expressive, it does not contain local module mechanisms.

To fix this problem, a modern way to add local declarations is to introduce declarations-implication expressions (DI expressions) of the form:

\[
D \rightarrow E
\]

where \( D \) is a set of function declarations. This expression is adapted from the work in [8].

The above has the following intended semantics: the MI/MQ declarations in \( D \) are first processed and then are to be added to the current program in the course of evaluating \( E \).

This paper proposes an extension of the core functional languages with DI/MI/MQ expressions.

3. Examples

We assume a fibonacci module \( mf \) and a prime module \( mp \) which respectively contains the definitions of \( fib(n) \) and \( prime(n) \).

% fibonacci module.
% \( fib(n) \) returns \( n \)th Fibonacci number.
module prime
\[\text{prime}(n) = \text{prime}_{aux}(n, n - 1).\]

\[\text{prime}_{aux}(X) = \ldots.\]

An illustration of DI expressions is provided by the following definition of the function \(\text{prime}_{fib}(n)\) which returns true if \(n\)th Fibonacci number is prime:

\[
\text{prime}_{fib}(X) =
\begin{align*}
  \text{prime}_{fib}(n) &= \left(\text{fib}(n) = v\right)^{/mf} \\
  &\rightarrow (\text{prime}(v) = w)^{/mp} \rightarrow \text{prime}(\text{fib}(n))
\end{align*}
\]

The body of the definition above contains DI expressions. As an example, evaluating \(\text{prime}_{fib}(3)\) would result in adding all the declarations in \(mf, mp\), and then evaluating \(\text{prime}(\text{fib}(3))\). The machine returns true, as \(2\) is prime.

MQ declarations are intended to add only some (logical consequences) of a module to the current module. An illustration of this aspect is shown here.

\[
\text{prime}_{fib}(n) = (\text{fib}(n) = v)^{/mf} \\
\rightarrow (\text{prime}(v) = w)^{/mp} \rightarrow \text{prime}(\text{fib}(n))
\]

The body of the definition above contains MQ declarations. As a particular example, evaluating \(\text{prime}_{fib}(3)\) would result in adding only the two declarations \(\text{fib}(3) = 2\) and \(\text{prime}(2) = true\) to the program, and then evaluating \(\text{prime}(\text{fib}(3))\). That is, \(v\) is set to \(2\), \(w\) is set to \(true\).

4. The Language

The language is a version of the core functional languages with DI/MI/MQ expressions. It is described by \(E\)- and \(D\)-rules given by the abstract syntax as follows:

\[
E ::= c \mid x \mid h(E, \ldots, E) \mid D \rightarrow E \mid T
\]
\[
D ::= /m \mid f(t_1, \ldots, t_n) = E \mid (f(t_1, \ldots, t_n) = v)^{/m} \mid D \land D
\]

In the abstract syntax, \(E\) and \(D\) denote the expressions and the definitions, respectively. In the rules above, \(c\) is a constant, \(x, v\) are variables, \(t\) is a term which is either a variable or a constant, and \(m\) is a module name. A set of function definitions \(D\) is called a program in this language.

We will present the semantics of this language in the style of [7]. It consists of two steps. The first step is to preprocess and instantiate all the querying declarations in \(D\) by invoking queries to their corresponding module. The second step is described as a set of rules in Definition 1. The evaluation strategy assumed by these rules is an eager evaluation. Note that execution alternates between two phases: the evaluation phase defined by \(\text{eval}\) and the backchaining phase by \(\text{bc}\).

In the evaluation phase, denoted by \(\text{eval}(D, E, K)\), the machine tries to evaluate an expression \(E\) from the program \(D\), a set of definitions, to get a value \(K\). Note that these rules written in logic-programming style, i.e., \(\text{eval}(D, E, K)\) is true if the evaluation result of \(E\) in \(D\) is \(K\). For instance, if \(E\) is a function call \(h\), the machine first evaluates all of its arguments and then looks for a definition of \(h\) in the program in the backchaining mode.

The rules (1) – (4) describe the backchaining mode, denoted by \(\text{bc}(D_1, D, h, K)\). In the backchaining mode, the machine tries to evaluate a function call \(h\) by using the function definition in the program \(D_1\).

**Definition 1.** Let \(E\) be an expression and let \(D\) be a program. Then the notion of evaluating \(D, E\) to a value \(K \leftarrow \text{eval}(D, E, K)\) is defined as follows:

1. \(\text{bc}(h(c_1, \ldots, c_n), E, D, h(c_1, \ldots, c_n), K)\) if \(\text{eval}(D, E, K)\), % switch to evaluation mode.
2. \(\text{bc}(D_1 \land D_2, D, h(c_1, \ldots, c_n), K)\) if \(\text{bc}(D_1, D, h(c_1, \ldots, c_n), K)\), % look for \(h\) in \(D_1\)
3. \(\text{bc}(D_1 \land D_2, D, h(c_1, \ldots, c_n), K)\) if \(\text{bc}(D_2, D, h(c_1, \ldots, c_n), K)\), % look for \(h\) in \(D_2\)
4. \(\text{bc}(h(x_1, \ldots, x_n), E, D, h(c_1, \ldots, c_n), K)\) if \(\text{bc}(h(c_1/x_1, \ldots, c_n/x_n) = E', D, h(c_1, \ldots, c_n), K)\) where \(E' = [c_1/x_1, \ldots, c_n/x_n]E\). % argument passing to \(h\) and \(E\).
5. \(\text{eval}(D, T, T)\). % \(T\) is always a success.
6. \(\text{eval}(D, c, c)\). % success if \(c\) is a constant.
7. \(\text{eval}(D, h(c_1, \ldots, c_n), K)\) if \(\text{bc}(D, D, h(c_1, \ldots, c_n), K)\). % switch to backchaining by making a copy of \(D\) for a function call.
8. \(\text{eval}(D, h(E_1, \ldots, E_n), K)\) if \(\text{eval}(D, E_1, c_1)\) and \(\text{eval}(D, h(c_1, \ldots, c_n), K)\). % evaluate the arguments first.
9. \(\text{eval}(D, D_1 \rightarrow E, K)\) if \(\text{eval}(D \land D_1, E, K)\) % DI expressions.
10. \(\text{eval}(D, D_1 \land (m \land D_2 \rightarrow E, K)\) if \(\text{eval}(D, D_1 \land (m \land D_2 \rightarrow E, K)\), provided that \(D_1\) is the declarations contained in module \(m\). % MI expressions.
11. \(\text{eval}(D, D_1 \land (f(t_1, \ldots, t_n) = v)^{m \land D_2 \rightarrow E, K}\) if \(\text{eval}(D, D_1 \land (f(t_1, \ldots, t_n) = w)^{m \land D_2 \rightarrow E, K}\), provided that \(w\) is the value obtained by evaluating
\[ f(t_1, \ldots, t_n) \text{ w.r.t. the module } m. \% \text{ MQ expressions.} \]

Note that, in rule (11), a module that is queried could itself query other modules. For simplicity, other popular constructs such as if-then-else and pattern matching are not shown above. If \( \text{eval}(D, E, K) \) has no derivation, it returns a failure.

5. Conclusion

In this paper, we proposed an extension to functional languages with DI/MI/MQ expressions. These expressions are particularly useful for avoiding qualified names in functional languages.

The MQ expressions can be implemented by treating them like exceptions. That is, when an MQ expression is encountered, suspend the current execution, switch to another execution (That is, evaluating a query with respect to another module) and then resume the suspended execution.

Our ultimate interest is to design a module system for Computability Logic [2]–[6].

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