Incorporating User Interaction into Imperative Languages

Keehang Kwon
khkwon@dau.ac.kr

Abstract: In this paper, we present two new forms of the write statement: one of the form write\(x\); \(G\) where \(G\) is a statement and the other of the form write\(x\); \(D\) where \(D\) is a module. The former is a generalization of traditional write statement and is quite useful. The latter is useful for implementing interactive modules.

1 Introduction

In this article, we describe a variant of C with some features that are inspired by the work of [2]. These features include

(1) A write statement dual to the read statement which has the form of write\(x\); \(G\). This statement has the following new semantics: the machine finds a value \(v\) for \(x\) so that the statement \(G\) can be successfully completed.

(2) A interactive module of the form write\(x\); \(D\) where \(D\) is a set of procedure declarations. This write statement has the following interchanged semantics: the user chooses a value \(v\) for \(x\).

The notion of interactive methods/modules is quite indispensable in modern imperative languages. Interactive methods interact with the environment, therefore providing some form of interactive computing. This paper aims to achieve interaction by providing interactive modules to imperative languages. Thus we allow, within a module, declarations of the form write\(x\) where \(x\) is a variable. The intended meaning is that the value of \(x\) is obtained dynamically from the environment. To see the usefulness of interactive modules, let us consider the following method which produces the mobile phone number of each employee.

write\(y\);
phone\(x\) =
case Tom : number = 8375;
case Jill : number = 2312;
case Kim : number = y;

In the above, the variable \( y \) - which is Kim’s Phone - will be obtained at run time by requesting the environment to type in Kim’s phone number.

Implementing our language poses no serious problem. In this paper, we introduce one way of implementing interaction. Our implementation scheme is the following: when a module is loaded, the variables in the write statements will be replaced by the input values typed in by the environment.

2 The Language

The language is a subset of the core (untyped) C with some extensions. It is described by \( G \)-, \( D \)- and \( E \)-formulas given by the syntax rules below:

\[
G ::= \text{true} \mid A \mid x = \text{exp} \mid G; G \mid \text{write}(x); G \\
D ::= A = G \mid \forall x \ D \mid D \land D \\
E ::= D \mid \text{write}(x); E
\]

In the above, \( A \) represents a head of an atomic procedure definition of the form \( p(x_1, \ldots, x_n) \). A \( D \)-formula is a set of procedure declarations. A \( E \)-formula is an interactive module.

In the transition system to be considered, a \( G \)-formula will function as a statement and an \( E \)-formula enhanced with the machine state (a set of variable-value bindings) will constitute a program. Thus, a program is a pair \( \langle E, \theta \rangle \) where \( \theta \) represents the machine state. \( \theta \) is initially empty and will be updated dynamically during execution via the assignment statements.

We will present an interpreter for our language via a proof theory [1, 6]. Note that in the initialization phase (denoted by \( \text{exec}(P, G, P') \)), our interpreter replaces all the variables in \( \text{write} \) in \( P \) with new input values from the environment. After that, our interpreter proceeds like traditional C interpreter. To be specific, it alternates between the execution phase and the backchaining phase. In the execution phase (denoted by \( \text{ex}(P, G, P') \)), it executes a statement \( G \) with respect to \( P \) and produce a new program \( P' \) by reducing \( G \) to simpler forms. The rules (6)-(9) deal with this phase. If \( G \) becomes a procedure call, the machine switches to the backchaining
mode. This is encoded in the rule (5). In the backchaining mode (denoted by \(bc(D, P, A, P')\)), the interpreter tries to find a matching procedure for a procedure call \(A\) inside the module \(D\) by decomposing \(D\) into a smaller unit (via rule (4)-(5)) and reducing \(D\) to its instance (via rule (2)) and then backchaining on the resulting definition (via rule (1)). To be specific, the rule (2) basically deals with argument passing: it eliminates the universal quantifier \(x\) in \(\forall xD\) by picking a value \(t\) for \(x\) so that the resulting instantiation, \([t/x]D\), matches the procedure call \(A\). The notation \(S\) seqand \(R\) denotes the sequential execution of two tasks. To be precise, it denotes the following: execute \(S\) and execute \(R\) sequentially. It is considered a success if both executions succeed. Similarly, the notation \(S\) parand \(R\) denotes the parallel execution of two tasks. To be precise, it denotes the following: execute \(S\) and execute \(R\) in any order. It is considered a success if both executions succeed. The notation \(S ← R\) denotes reverse implication, i.e., \(R → S\).

**Definition 1.** Let \(G\) be a statement and let \(P\) be a program. Then the notion of executing \(⟨P, G⟩\) and producing a new program \(P'\) – \(\text{exec}(P, G, P')\) – is defined as follows:

1. \(bc((A = G_1), P, A, P_1) ← ex(P, G_1, P_1). \quad \% A matching procedure for \(A\) is found.\)
2. \(bc(∀xD, P, A, P_1) ← bc([t/x]D, P, A, P_1). \quad \% \text{argument passing}\)
3. \(bc(D_1 \land D_2, P, A, P_1) ← bc(D_1, P, A, P_1). \quad \% \text{look for a matching procedure in } D_1.\)
4. \(bc(D_1 \land D_2, P, A, P_1) ← bc(D_2, P, A, P_1). \quad \% \text{look for a matching procedure in } D_2.\)
5. \(ex(⟨D, θ⟩, A, P_1) ← bc(D, P, A, P_1). \quad \% A is a procedure call\)
6. \(ex(P, true, P). \quad \% \text{True is always a success.}\)
7. \(ex(P, x = exp, P \cup \{⟨x, exp'⟩\}) ← eval(P, exp, exp'). \quad \% \text{In the assignment statement, it evaluates } exp \text{ to get } exp'. \text{ The symbol } \cup \text{ denotes a set union but } ⟨x, V⟩ \text{ in } P \text{ will be replaced by } ⟨x, E'⟩.\)
8. \(ex(P, G_1; G_2, P_2) ← ex(P, G_1, P_1) \text{ seqand } ex(P_1, G_2, P_2). \quad \% \text{a sequential composition}\)
(9)  \[ ex(P, \textit{write}(x); G_1, P_1) \leftarrow \]
\hspace{1cm} choose (and print) a value \( v \) for \( x \) so that \( ex(P_1, [v/x]G_1, P_1) \). \% write statement

(10) \[ \textit{exec}((\textit{write}(x_1) \ldots \textit{write}(x_n)D, \theta), G, P_1) \leftarrow \]
\hspace{1cm} \textit{read}(y_1) \ldots \textit{read}(y_n) \textit{seqand} \ ex([y_1, \ldots, y_n]D, \theta), G, P_1). \% \textit{In the}
\hspace{1cm} \textit{initialization phase, each} \( x_i \) \textit{is replaced with a new input value} \( y_i \) \textit{typed}
\hspace{1cm} \textit{by the environment.}

If \( ex(P, G, P_1) \) has no derivation, then the interpreter returns the failure.
The rule (9) deals with the new feature.

### 3 Examples

The following code displays the employee’s age to be determined at run time.

```plaintext
write(y1);
write(y2);
write(y3);
age(x) =
    switch (x) {
        case tom: age = y1; break;
        case kim: age = y2; break;
        case sue: age = y3; break;
        default: age = 0;
    }
```

Now consider the procedure call `age(tom)`. The above code will be changed to the one below in the initialization phase assuming the environment typed in 30,40,22 for \( y_1,y_2,y_3 \) respectively.

```plaintext
age(x) =
    switch (x) {
        case tom: age = 30; break;
        case kim: age = 40; break;
        case sue: age = 22; break;
        default: age = 0;
```
Then execution proceeds in the usual way.

4 Conclusion

In this paper, we have presented a new form of the write statement of the form \textit{write}(x); S. This statement is a generalization of traditional write statement \textit{write}(exp), as we can write the latter as \textit{write}(x); x == exp. Here we assume that we allow boolean expressions as statements. In addition, we have presented a notion of interactive modules. The notion of interactive modules is an indispensable tool in modern interactive programming.

5 Acknowledgements

This work was supported by Dong-A University Research Fund.

References

[1] G. Kahn, “Natural Semantics”, In the 4th Annual Symposium on Theoretical Aspects of Computer Science, LNCS vol. 247, 1987.

[2] G. Japaridze, “Introduction to computability logic”, Annals of Pure and Applied Logic, vol.123, pp.1-99, 2003.

[3] G. Japaridze, “Sequential operators in computability logic”, Information and Computation, vol.206, No.12, pp.1443-1475, 2008.

[4] K. Kwon, S. Hur and M. Park, “Improving Robustness via Disjunctive Statements in Imperative Programming”, IEICE Transations on Information and Systems, vol.E96-D, No.9, pp.2036-2038, September, 2013.

[5] J. Hodas and D. Miller, “Logic Programming in a Fragment of Intuitionistic Linear Logic”, Information and Computation, vol.110, No.2, pp.327-365, 1994.
[6] D. Miller, G. Nadathur, F. Pfenning, and A. Scedrov, “Uniform proofs as a foundation for logic programming”, Annals of Pure and Applied Logic, vol.51, pp.125–157, 1991.

[7] D. Miller, G. Nadathur, Programming with higher-order logic, Cambridge University Press, 2012.