Pattern Matching via Choice Existential Quantifications in Imperative Languages

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Abstract: Selection statements – if-then-else, switch and try-catch – are commonly used in modern imperative programming languages. We propose another selection statement called a choice existentially quantified statement. This statement turns out to be quite useful for pattern matching among several merits. Examples will be provided for this statement.

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1 Introduction

Most imperative languages have selection statements to control execution flow. A selection statement allows the machine to choose between two or more statements during execution. Selection statements typically include if-then-else and try-catch. Unfortunately, these statements are not sufficient for expressing nondeterministic tasks in a concise way.

To overcome these problems, inspired by the work in [2, 3], we propose a new kind of selection statements called choice existentially quantified statements (CEQ statements). This statement is quite simple and of the form

\[ \text{choose}(x)G \]

where \( G \) is a statement. This has the following execution semantics:

\[ \text{ex}(P, \text{choose}(x)G) \text{ if } \text{ex}(P, [t/x]G) \]
where the term (or the value) $t$ is chosen by the machine and $\mathcal{P}$ is a set of procedure (and function) definitions. In the above definition, the machine chooses a *successful* term $t$ and then proceeds with executing $[t/x]G$.

We also introduce a variant of the above, $\text{choose}(x \in S) \ G$, which is called a *bounded choice existentially quantified statement* (BCEQ statement). Bounded quantifiers differ from unbounded quantifiers in that bounded quantifiers restrict the range of the variable $x$ to the set $S$. Thus, bounded quantifiers make it easier for the machine to choose a successful term.

It can be easily seen that our new statement subsumes the $\text{print}$ statement. For example, let $G$ be a statement and let $E$ be an expression. Then $G; \text{print}(E)$ can be converted to

$$\text{choose}(x)(G; \ x == E)$$

provided $x$ does not appear free in $G$ and the choice of $x$ is visible to the user. In the above, note that a boolean condition is a legal statement in our language, as we shall see in Section 2.

The CEQ statement makes it simple to represent complex, nondeterministic tasks. For example, the following statement represents the task of finding (and printing) an index $x$ (between 1 and 50) such that the $x$th Fibonacci number is 5.

$$\text{choose}(x \in \{1..50\})(5 == \text{fib}(x))$$

In this case, the machine will find the value of 6 for $x$ after some search.

Another example is the following. This statement represents the task of finding and printing the values of the tenth Fibonacci number and the factorial of 20.

$$\text{choose}(x) \ \text{choose}(y)(x == \text{fib}(10); \ y == \text{fact}(20))$$

Note that the above program is compact and easy to read.

This paper focuses on the core of Java. This is to present the idea in a concise way. The remainder of this paper is structured in the following way. We describe the core Java with the CEQ statements in Section 2. In Section 3, we present some example of Java choose. Section 4 concludes the paper.

## 2 The Language

The language is a subset of the core (untyped) Java with some extensions. It is described by $G$- and $D$-formulas given by the syntax rules below:
\[G ::= A \mid \text{cond} \mid x = E \mid G; G \mid \text{choose}(x)G \mid \text{choose}(x \in S)G\]

\[D ::= A = G \mid \forall x \ D\]

In the above, \textit{cond} represents a boolean condition, \(S\) represents a set and \(E\) is an expression. \(A\) represents a head of an atomic procedure definition of the form \(p(x_1, \ldots, x_n)\) where each \(x_i\) is a variable. A \(D\)-formula is called a procedure (and function) definition.

In the transition system below, \(G\)-formulas will act as the main program (or statements), and a set of \(D\)-formulas enhanced with the machine state (a set of variable-value bindings) will act as a program.

We will present an execution semantics via a proof theory \[1, 6, 5, 7\]. The rules defines what it means to execute the main task \(G\) from a program \(P\). These rules define precisely what is a success and failure. Below the notation \(D; P\) denotes \(\{D\} \cup P\) but with the \(D\) formula being distinguished (marked for backchaining). Note that execution alternates between two phases: the main phase (the phase of executing the main program) and the backchaining phase (one with a distinguished clause). The notation \(S; R\) denotes the following: execute \(S\) and execute \(R\) sequentially. It is considered a success if both executions succeed.

**Definition 1.** Let \(G\) be a main task and let \(P\) be a program. Then the notion of executing \((P, G)\) successfully and producing a new program \(P' - ex(P, G, P')\) – is defined as follows:

1. \(ex((A = G_1); P, A)\) if \(ex(P, G_1)\) and \(ex(D; P, A)\).
2. \(ex(\forall x D; P, A)\) if \(ex([s/x]D; P, A)\) where \(s\) is a value (or a term). % argument passing
3. \(ex(P, A)\) if \(D \in P\) and \(ex(D; P, A)\). % a procedure call
4. \(ex(P, \text{cond}; P)\) if \(eval(P, \text{cond}, \text{cond}')\) and \text{cond}' is true. % evaluating boolean condition \text{cond} to \text{cond}'.
5. \(ex(P, x = E, P \not\cup \{(x, E')\})\) if \(eval(P, E, E')\). % the assignment statement. If evaluating \(E\) fails, then the whole statement fails. Here, \(\not\cup\) denotes a set union but \(\langle x, V\rangle\) in \(P\) will be replaced by \(\langle x, E'\rangle\).
6. \(ex(P, G_1; G_2, P_2)\) if \(ex(P, G_1, P_1)\) sand \(ex(P_1, G_2, P_2)\).
7. \(ex(P, \text{choose}(x)G, P_1)\) if \(ex(P, [t/x]G, P_1)\) where \(t\) is a successful value for \(x\) chosen by the machine.
(8) \( ex(P, choose(x \in S)G, P_1) \) if \( x \in S \) and \( ex(P, [t/x]G, P_1) \) where \( t \) is a successful value for \( x \) chosen by the machine.

If \( ex(P, G, P_1) \) has no derivation, then the machine returns the failure.

3 Examples

Pattern matching is a useful feature in modern programming languages. While there have been several attempts to add pattern matching to imperative paradigm [8], these attempts are rather complex and rely on refining the type system. The simplest approach to adding pattern matching, which requires no type systems, is to allow first-order terms as data. For example, \( tuple(tom, 31, male) \) would be a legitimate data. In such a case, our \textit{choose} statement is well-suited for pattern matching. For example, the following statement is a simple implementation of destructuring an employee’s record into three components.

\begin{verbatim}
getrecord(emp) {
    choose(name) choose(age) choose(sex) (tuple(name, age, sex) == emp);
}
\end{verbatim}

It is not easy to write concise codes for this task in traditional languages. Fortunately, it is quite simple in our setting.

4 Conclusion

In this paper, we have considered an extension to a core Java with a new selection statement. This extension allows \textit{choose}(x)G where \( x \) is a variable and \( G \) is a statement. This statement makes it possible for the core Java to perform nondeterministic tasks. Our language gives, in a sense, a logical status to Java. This means that other logical connectives such as disjunctions can be added. Some progress has been made towards this direction [4].

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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, 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.

[8] S. Ryu, C. Park and G. Steel Jr. “Adding Pattern Matching to Existing Object-Oriented Languages”, FOOL ’10, Nevada, USA, 2010.