Anonymous Variables in Imperative Languages

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Abstract:
In this paper, we bring anonymous variables into imperative languages. Anonymous variables represent don’t-care values and have proven useful in logic programming. To bring the same level of benefits into imperative languages, we describe an extension to C with anonymous variables.

1 Introduction

The notion of anonymous variables was introduced in logic programming. Anonymous variables represent don’t-care values. As we shall see later, they provide some convenience to programming. This paper aims to bring anonymous variables into imperative languages. Thus we allow the symbol \_ which denotes an anonymous variable. To see some use of anonymous variables, let us consider the following procedure which produces the amount of the tuition of a student \( x \) with major \( m \).

\[
\forall x \forall m \text{ tuition}(x,m) =
\begin{align*}
\text{case medical : amount} & = \$10K; \\
\text{case english : amount} & = \$5K; \\
\text{case physics : amount} & = \$5K;
\end{align*}
\]

Note that the above program is independent of \( x \). To represent this, we replace the above with

\[
\forall m \text{ tuition}(\_m) =
\begin{align*}
\text{case medical : amount} & = \$10K; \\
\text{case english : amount} & = \$5K; \\
\text{case physics : amount} & = \$5K;
\end{align*}
\]

which is an abbreviation of
∀^b x ∀m tuition(x,m) =
  
  case medical : amount = $10K;
  case english : amount = $5K;
  case physics : amount = $5K;

where ∀^b x is called a blind universal quantifier\footnote{This concept was originally introduced in \cite{2}, but with different notations. For example, the blind universal quantifier is denoted by ∀x.}. The main difference between ∀^b x and ∀x is that, in the former, the instantiation of x will not be visible to the user and will not be recorded in the execution trace, while in the latter, it will.

Now consider the following procedure call.

\[ tuition(kim, medical); print(amount). \]

Then the machine will print “$10K” as usual.

We also introduce its counterpart \( \exists^b x p(x_1, \ldots, x_n) \) where \( p(x_1, \ldots, x_n) \) is a procedure call. In this case \( x_i \) becomes an anonymous variable.

Implementing anonymous variables is not too difficult. Below we describe a modest method to bring anonymous variables into imperative language. During execution anonymous variables will be replaced by some value. Choosing the proper value for anonymous variables is often not trivial. Typically anonymous variables will be replaced by uninstantiated variables. These variables will be instanced later when enough information is gathered. This process is typically known as unification. Unification process will not be described here and we refer \cite{4} to the reader.

2 The Language

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

\[
G ::= \text{true} \mid p(x_1, \ldots, x_n) \mid \exists x p(x_1, \ldots, x_n) \mid x = E \mid G; G \\
D ::= A = G \mid \forall x D \mid \forall^b x D \mid D \land D
\]

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.
In the execution, a $G$-formula will function as a statement and a set of $D$-formulas enhanced with the machine state (a set of variable-value bindings) will constitute a program. Thus, a program is a union of two disjoint sets, i.e., $\{D_1, \ldots, D_n\} \cup \theta$ 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 natural semantics [1]. It alternates between the execution phase and the backchaining phase. In the execution phase (denoted by $ex(\mathcal{P}, G, \mathcal{P}')$), it executes a statement $G$ with respect to $\mathcal{P}$ and produce a new program $\mathcal{P}'$ by reducing $G$ to simpler forms. The rules (7)-(10) deal with this phase. If $G$ becomes a procedure call, the machine switches to the backchaining mode. This is encoded in the rule (6). In the backchaining mode (denoted by $bc(D, \mathcal{P}, A, \mathcal{P}')$), 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),(3)) 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 $S \text{ seq} and R$ 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 $S \text{ par} and R$ 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 $S \leftarrow R$ denotes reverse implication, i.e., $R \rightarrow S$.

**Definition 1.** Let $G$ be a statement and let $\mathcal{P}$ be a program. Then the notion of executing $\langle \mathcal{P}, G \rangle$ and producing a new program $\mathcal{P}' – ex(\mathcal{P}, G, \mathcal{P}')$ – is defined as follows:

1. $bc((A = G_1), \mathcal{P}, A, \mathcal{P}_1) \leftarrow ex(\mathcal{P}, G_1, \mathcal{P}_1)$. % A matching procedure for $A$ is found.
2. $bc(\forall xD, \mathcal{P}, A, \mathcal{P}_1, ) \leftarrow bc([t/x]D, \mathcal{P}, A, \mathcal{P}_1)$. % argument passing. Instantiation $(x, t)$ will be recorded.
3. $bc(\forall d D, \mathcal{P}, A, \mathcal{P}_1, ) \leftarrow$
bc([t/x]D, P, A, P_1). % argument passing. Instantiation \((x, t)\) will not be recorded.

(4) \(bc(D_1 \land D_2, P, A, P_1) \leftarrow bc(D_1, P, A, P_1). %\) look for a matching procedure in \(D_1\).

(5) \(bc(D_1 \land D_2, P, A, P_1) \leftarrow bc(D_2, P, A, P_1). %\) look for a matching procedure in \(D_2\).

(6) \(ex(P, p(x_1, \ldots, x_n), P_1) \leftarrow (D \in P) \text{ parand } bc(D, P, A, P_1). %\) \(p(x_1, \ldots, x_n)\) is a procedure call.

(7) \(ex(P, \exists^b x_i p(x_1, \ldots, x_n), P_1) \leftarrow ex(P, [t/x_i]p(x_1, \ldots, x_n), P_1). % x_i is an anonymous variable.

(8) \(ex(P, \text{true}, P_1). %\) True is always a success.

(9) \(ex(P, x = E, P \uplus \{(x, E')\}) \leftarrow eval(P, E, E'). %\) In the assignment statement, it evaluates \(E\) to get \(E'\). The symbol \(\uplus\) denotes a set union but \(\langle x, V \rangle\) in \(P\) will be replaced by \(\langle x, E' \rangle\).

(10) \(ex(P, G_1; G_2, P_2) \leftarrow ex(P, G_1, P_1) \text{ seqand } ex(P_1, G_2, P_2). %\) a sequential composition.

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

## 3 Examples

Let us consider again the example in the Introduction section.

\begin{align*}
\forall x \forall m \text{ tuition(x,m) =} \\
\quad \text{case medical : amount } = \$10K; \\
\quad \text{case english : amount } = \$5K; \\
\quad \text{case physics : amount } = \$5K;
\end{align*}

Now consider the following procedure call.

\[
tuition(_\_	ext{ medical}); \text{print(amount)}.
\]

Note that \(_\_\) is used in the above, as there is no need to specify a student.

The above can be understood as an abbreviation of

\[
\exists^b x \text{ tuition(x, medical); print(amount)}.
\]
4 Conclusion

In this paper, we have presented a notion of anonymous variables in the setting of imperative languages. We introduce ∀ₜ for anonymous variables in procedure declarations and ∃ₜ for anonymous variables in procedure calls. Anonymous variables provide some convenience to programmers.

References

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