A Logical Approach to Event Handling in Imperative Languages

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Abstract: While event handling is a key element in modern interactive programming, it is unfortunate that its theoretical foundation is rather weak. To solve this problem, we propose to adopt a game-logical approach of computability logic [2] to event handling.

keywords: event handling, game semantics, interaction, computability logic.

1 Introduction

Event handling is a key element in modern programming paradigm such as GUI programming. Despite the importance, modern imperative languages have lacked theoretical foundations for representing events. To solve this, we first observe that the problem of representing events reduces to the problem of representing objects with switching capabilities (by the user). For example, an earphone can be switched by the user from being disconnected to being connected.

To represent objects with switching capabilities, we propose to adopt a sequential-choice-disjunctive operator in computability logic [2]. To be precise, a sequential-choice-disjunctive statement of the form schoo(D_1, \ldots, D_n) is allowed in the declarations (▽ was originally used in [2],) where each D_i is a constant declaration or a procedure declaration. This statement has the following semantics: Use D_1 first. If the user types Esc, then switch to use D_2. For example, an earphone, declared as schoo(on == 0, on == 1), indicates that it is originally disconnected. However, if the user types Esc, then it switches its status to being connected. Hence, it provides a form of dynamic knowledgebases[2].

On the other hand, the use of schoo in the main program requests the machine to sequentially choose one among several alternatives. Therefore, it is identical to the old if-then-else statement.
2 The Language

The language is core C with procedure definitions. It is described by $G$, $C$- and $D$-formulas given by the syntax rules below:

$$
\begin{align*}
G &::= \top | \text{print}(x) | A | \text{cond} | x = E | G; G | \text{schoo}(G_1, \ldots, G_n) \\
C &::= c == E | A = G | \forall x C \\
D &::= C | D \land D | \text{schoo}(D, \ldots, D)
\end{align*}
$$

Here, $\top$ is a true statement, $A$ represents a head of an atomic procedure of the form $p(x_1, \ldots, x_n)$, $x = E$ is an assignment statement and $\text{cond}$ is a boolean condition. Note that a boolean condition is a legal statement in this language. $c == E$ is a constant declaration with value $E$.

In the sequel, $G$-formulas will function as the main statement, and a $D$-formula will constitute a program. $\theta$ represents the substitution state which is a set of variable-value bindings. Note that $\theta$ is initially set to an empty set and will be updated during execution via the assignment statements.

We need some definitions first. We understand a formula $K \supset H$ as $\neg K \lor H$ and a procedure declaration $A = G$ as $G \supset A$. Now an elementarization of a formula $F$ is obtained by

- replacing in $F$ all the surface occurrences of $\text{schoo}(G_0, \ldots, G_n)$ by $G_0$,
- replacing in $F$ all the surface occurrences of $\text{schoo}(D_0, \ldots, D_n)$ by $D_0$,
- replacing in $F$ all the assignment statements by $\bot$,
- replacing in $F$ all the $\text{print}$ statements by $\bot$,
- replacing in $F$ all the occurrences of $G_0; G_1$ by $G_0 \land G_1$

A formula is said to be stable if its elementarization is classically valid.

Given $D$ and $G$, we assume that the relation $\text{stable}$ which does the following is available.

- $\text{stable}(D, G, 0)$ if $D \supset G$ is instable and a move is available for the machine.
- $\text{stable}(D, G, -1)$ if $D \supset G$ is instable and no moves are available for the machine.

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• stable\((D, G, 1)\) if \(D \supset G\) is stable and a move is available for the user.

• stable\((D, G, 2)\) if \(D \supset G\) is stable and no moves are available for the user.

We will present an interpreter which is adapted from \([2]\). The basic idea is for the execution to avoid backtrackings because backtracking is not acceptable in interactive programming.

Note that this interpreter alternates between the machine move phase and the user move phase. In the machine move phase (denoted by \(ex_m\)), the machine tries to make a move by executing the assignment statement, the print statement or the schoo statement. In the user move mode (denoted by \(ex_u\)), the user tries to make a move and produce a new program \(D'\) by executing the schoo declarations.

Below, we need some notations at the meta level: \(S\) and \(R\) denotes the sequential execution of two tasks. \(S\) and \(R\) denotes the parallel conjunctive execution of two tasks. \(S\) or \(R\) denotes the parallel disjunctive execution of two tasks. \(S\) choose \(R\) denotes the selection between two tasks.

Below, the notation \(S \leftarrow R\) denotes reverse implication, i.e., \(R \rightarrow S\) at the meta level.

**Definition 1.** Let \(G\) be a main statement, let \(D\) be a program and let \(\theta\) be a substitution. Then the notion of executing \(\langle D, G, \theta \rangle\) successfully and producing a new substitution \(\theta_1\) – \(ex(D, G, \theta, \theta_1)\) – is defined as follows:

\[
\begin{align*}
\text{ex}(D, G, \theta, \theta_1) & \leftarrow \\
\text{stable}(D, G, I) & \text{ sand } % \text{ check first whether the execution is stable} \\
\text{choose}( & \\
I = 1 & \text{ sand } \text{read}(EV) \text{ sand } ex_u(D, EV, D_1) \text{ sand } \text{exec}(D_1, G, \theta, \theta_1), \% \text{ user’s move.} \\
I = 2 & , \% \text{ nothing for the user to do. Execution succeeds.} \\
I = 0 & \text{ sand } ex_m(D, G, \theta, G', \theta') \text{ sand } \text{ex}(D, G', \theta', \theta_1), \% \text{ machine’s move} \\
I = -1 & \% \text{ nothing for the machine to do. Execution fails.} \\
) 
\end{align*}
\]

where \(ex_m(D, G, \theta, G_1, \theta_1)\) is defined as follows:

Note that this \(ex_m\) phase alternates between two subphases: the backchaining subphase and the goal reduction subphase until the machine makes a move.

**Definition 2.** Let \(G\) be a main statement, let \(D\) be a program and let \(\theta\) be a substitution. Then the notion of the machine making a single move
Definition 3. Let $D$ be a program. Then the notion of the user making a move in $D$ using $EV$ and producing a new program $D'$ -- $ex_u(D, EV, D')$ -- is defined as follows:

(1) \( ex_u(C, w.\text{Esc}, C) \).
(2) \(exe_u(D_0 \land D_1, w.Esc, D_0' \land D_1') \leftarrow w\) is the address of \(D_0\) and \(exe_u(D_0, w'.Esc, D_0')\). Here \(w'\) is the location adjusted from \(w\).

(3) \(exe_u(D_0 \land D_1, w.Esc, D_0 \land D_1') \leftarrow w\) is the address of \(D_1\) and \(exe_u(D_1, w'.Esc, D_1')\). Here \(w'\) is the location adjusted from \(w\).

(4) \(exe_u(schoo(D_0, \ldots, D_n), w.Esc, schoo(D_1, \ldots, D_n)) \leftarrow\)
\(w\) is the address of \(schoo\). % event processed

3 Examples

The following code prints the price of a car, based on the user’s choice of a model.

% constant declaration
print(“type Esc to switch”);
schoo(model == BMW320, model == BMW520, model == BMW740)

with the following \(G\) formula:

schoo(  
    model == BMW320; price = $32,000; print(price),  
    model == BMW520; price = $54,000; print(price),  
    model == BMW740; price = $82,200; print(price))

Initially, the execution is instable. Therefore, the machine executes the first three statements and prints $32,000. As the execution becomes stable, the machine waits for the user to make a move (by switching to the second model). If the user did switch to the BMW520 by typing ESC, then the execution becomes instable and the machine also switches to the second one and so on. If the user makes no move, the machine keeps waiting.

4 Conclusion

So far, we have extended the basic C with the addition of \(schoo\) statements. These statements can be used in the declarations or in the main program and are useful for representing event handling.

Event handling is a very challenging subject, especially in the presence of asynchronous events. Note that we have dealt with simple synchronous events. In the future, we hope to include asynchronous events as well.
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