École normale supérieure 2023–2024

Programmation réactive et parallèle L. Mandel

Implement your own ReactiveML runtime

The goal of this exercise is to present the implementation of the ReactiveML runtime. The ReactiveML compiler with the skeleton of a runtime to complete is available here:

> https://www.lri.fr/~mandel/ens-m1/tp2-rml/rml-1.09. 08-tutorial-2023-12-17.tar.gz

Question 1

Compile and install this version of the compiler:

--> ./configure [--prefix PATH] --> make --> make install

Test your compiler with the examples provided in examples/tutorial. The following command will compile and execute the tests and compare them with the expected output.

```
--> cd examples/tutorial
--> ./test.sh
```

We are going complete the runtime which is defined in interpreter/lk_tutorial.ml. To use this runtime, a file a.rml must be compiled and linked with the compiler option -runtime Lk_tutorial.

```
--> rmlc -runtime Lk_tutorial a.rml
--> ocamlc -I 'rmlc -runtime Lk_tutorial -where' rmllib.cma a.ml
```

This runtime must implement the interpreter/lk_interpreter.mli interface.

1 Parallel composition

First, let us look at the parallel composition. Consider the following ReactiveML code:

```
let process par p q =
  run p || run q
```

The corresponding generated OCaml code is the following:

```
let par p q k ctrl =
  Lk_tutorial_record.rml_split_par 2
  (fun j ->
    let kj _ = Lk_tutorial_record.rml_join_par j k ()
    in
      [ Lk_tutorial_record.rml_run_v p kj ctrl;
      Lk_tutorial_record.rml_run_v q kj ctrl ])
```

Question 2

```
Update the implementation of the functions rml_split_par, sched, and rml_join_par to implement the parallel composition.
```

```
val rml_split_par:
    int -> (join_point -> (unit step) list) -> 'a step
val sched: unit -> unit
val rml_join_par: join_point -> unit step -> 'a step
```

These functions will use the current state variable.

ReactiveML also support parallel definitions as in the following example:

```
let process letand p q =
  let a = run p
  and b = run q in
  a + b
The corresponding generated code is:
let letand p q k ctrl =
  let body v =
    let (a, b) = v in
    Lk_tutorial_record.rml_compute (fun () \rightarrow a + b) k ()
  in
  Lk_tutorial_record.rml_split_par 2
    (fun j ->
       let a_ref = Pervasives.ref 4012
       and b_ref = Pervasives.ref 4012 in
       let get_vrefs () = (!a_ref, !b_ref) in
       [ Lk_tutorial_record.rml_run_v p
           (Lk_tutorial_record.rml_join_def j a_ref
              get_vrefs body)
           ctrl;
         Lk_tutorial_record.rml_run_v q
           (Lk_tutorial_record.rml_join_def j b_ref
              get_vrefs body)
           ctrl ])
```

Question 3

Implement the function rml_join_def that synchronize the termination of a parallel definition.

```
val rml_join_def:
    join_point -> 'a ref -> (unit -> 'b) -> 'b step -> 'a step
```

The first argument is the synchronization point, the second one is where to store the result of the branch, the third argument is a function that allows to read the result of all the branches and the last one is the continuation.

2 Logical time

Currently, the **pause** expression is not implemented.

Question 4

Add a list **next** of continuations to execute to the next instant in the global state.

Question 5

Update the code of rml_pause:

val rml_pause: unit step -> control_tree -> 'a step

Question 6

Update the function rml_make to prepare the execution of the next instant.

3 Communication

Question 7

Implement the emit and present constructs.

```
val rml_present_v:
    control_tree -> ('a, 'b) event -> unit step -> unit step -> 'c step
val rml_emit_v_v: ('a, 'b) event -> 'a -> unit step -> 'c step
```

The function Event.status n return a Boolean indicating if a value has been emitted on the signal n. The function Event.emit n v update the data structure n with the information of the emission of the value v.

Hint 1: The rml_present_v function uses of the global flag eoi indicating the end of instant and the list to_wake_up containing the lists to inspect at the end of instant.

Hint 2: Update the function rml_react to handle the end of instant. Do not forget to prepare the next state. The function Event.next () updates the signal environment for the next instant.

In the current implementation, the await immediate construct is implemented like:

let rec process await_immediate s =
 preset s then () else run await_immediate s

This implementation requires to test the presence of \mathbf{s} at each instant. Therefore, the execution of the following ReactiveML program is pretty slow:

```
let rec process slow acc i =
    if i > 0 then
        signal s in
        await s; print_int i; print_newline() ||
        run slow (s :: acc) (i - 1)
    else
        run Rml_list.iter (proc s -> pause; emit s) acc
let () =
    run slow [] 10000
```

Question 8

Modify the implementation of rml_await_immediate_v to allows passive waiting.

The expression await s(x) in ... can be decompose in two steps, await the presence of the signal and get its value: await immediate s; let s < x > in

The construct let s < x > in ... bind to x the value of the signal s in its body. The body is executed at the next instant. If the signal is not emitted, x takes the default value of the signal.

Question 9

Update the implementation of rml_get_v.

```
val rml_get_v:
   ('a, 'b) event -> ('b -> unit step) -> control_tree -> 'c step
```

The function Event.value n get the current value of the signal n and Event.default n gets its default value. The function rml_get_v can use the waiting list weoi that unconditionally executes the recorded step functions at the end of instant.

4 Control structure

ReactiveML provides high level control structures that allows to interrupt or suspend the execution of a process.

Question 10

With the current implementation, what is the difficulty in dealing with the following program?

Let's look now that the compilation of the following process:

```
let process killable s p =
  do run p
  until s done
```

The corresponding generated code is:

```
let killable s p k ctrl =
  Lk_tutorial_record.rml_start_until_v ctrl s
  (fun ctrl_until ->
      Lk_tutorial_record.rml_run_v p
        (Lk_tutorial_record.rml_end_until ctrl_until k) ctrl_until)
  (fun _ -> k)
```

Question 11

Update the implementation of rml_start_until_v.

```
val rml_start_until_v:
    control_tree -> ('a, 'b) event ->
        (control_tree -> unit step) -> ('b -> unit step) -> 'c step
```

This function will use the control_tree data structure. The function new_ctrl kind cond creates a new control tree node. Here, the node should be of kind Kill. The function eval_control_and_next_to_current handle the treatment of the control tree at the end of instant. It must be called in the rml_make function.

Question 12

Update the previously implemented operators to take into account the control structures.

Question 13

Update the implementation of rml_start_when_v to implement the suspension.

```
val rml_start_when_v:
    control_tree -> ('a, 'b) event ->
        (control_tree -> unit step) -> 'c step
```