Programming in Esterel

COMS W4995-02

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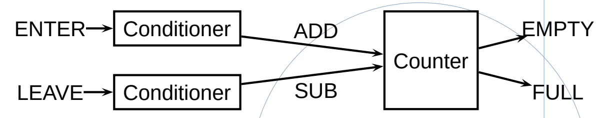
People Counter Example

Construct an Esterel program that counts the number of people in a room. People enter the room from one door with a photocell that changes from 0 to 1 when the light is interrupted, and leave from a second door with a similar photocell. These inputs may be true for more than one clock cycle.

The two photocell inputs are called ENTER and LEAVE. There are two outputs: EMPTY and FULL, which are present when the room is empty and contains three people respectively.

Source: Mano, *Digital Design*, 1984, p. 336

Overall Structure



Conditioner detects rising edges of signal from photocell.

Counter tracks number of people in the room.

Implementing the Conditioner

```
module Conditioner:
input A;
output Y;

loop
  await A; emit Y;
  await [not A];
end

end module
```

Testing the Conditioner

```
# esterel -simul cond.strl
# gcc -o cond cond.c -lcsimul # may need -L
# ./cond
Conditioner> ;
--- Output:
Conditioner> A;   # Rising edge
--- Output: Y
Conditioner> A;   # Doesn't generate a pulse
--- Output:
Conditioner> ;    # Reset
--- Output:
Conditioner> A;   # Another rising edge
--- Output: Y
Conditioner> ;
--- Output:
Conditioner> A;
--- Output: Y
```

Implementing the Counter: First Try

```
module Counter:
input ADD, SUB;
output FULL, EMPTY;

var count := 0 : integer in
  loop
    present ADD then if count < 3 then
       count := count + 1 end end;
    present SUB then if count > 0 then
       count := count - 1 end end;
    if count = 0 then emit EMPTY end;
    if count = 3 then emit FULL end;
    pause
  end
end

end module
```

Testing the Counter

```
Counter> ;
--- Output: EMPTY
Counter> ADD SUB;
--- Output: EMPTY
Counter> ADD;
--- Output:
Counter> SUB;
--- Output: EMPTY
Counter> ADD;
--- Output:
Counter> ADD;
--- Output:
Counter> ADD;
--- Output: FULL
Counter> ADD SUB;
--- Output:   # Oops: still FULL
```

Counter, second try

```
module Counter:
input ADD, SUB;
output FULL, EMPTY;

var c := 0 : integer in
  loop
    present ADD then
      present SUB else
        if c < 3 then c := c + 1 end
      end
    else
      present SUB then
        if c > 0 then c := c - 1 end
      end;
    end;
    if c = 0 then emit EMPTY end;
    if c = 3 then emit FULL end;
    pause
  end
end
end module
```

Testing the second counter

```
Counter> ;
--- Output: EMPTY
Counter> ADD SUB;
--- Output: EMPTY
Counter> ADD SUB;
--- Output: EMPTY
Counter> ADD;
--- Output:
Counter> ADD;
--- Output:
Counter> ADD;
--- Output: FULL
Counter> ADD SUB;
--- Output: FULL     # Working
Counter> ADD SUB;
--- Output: FULL
Counter> SUB;
--- Output:
Counter> SUB;
--- Output:
Counter> SUB;
--- Output: EMPTY
Counter> SUB;
--- Output: EMPTY
```

Assembling the People Counter

```
module PeopleCounter:
input ENTER, LEAVE;
output EMPTY, FULL;

signal ADD, SUB in
  run Conditioner[signal ENTER / A,
                         ADD / Y]
||
  run Conditioner[signal LEAVE / A,
                         SUB / Y]
||
  run Counter
end

end module
```

Vending Machine Example

Design a vending machine controller that dispenses gum once. Two inputs, N and D, are present when a nickel and dime have been inserted, and a single output, GUM, should be present for a single cycle when the machine has been given fifteen cents. No change is returned.

N = 

D = 

GUM = 

Source: Katz, *Contemporary Logic Design*, 1994, p. 389

Vending Machine Solution

```
module Vending:
input N, D;
output GUM;

loop
  var m := 0 : integer in
    trap WAIT in
      loop
        present N then m := m + 5; end;
        present D then m := m + 10; end;
        if m >= 15 then exit WAIT end;
        pause
      end
    end;
    emit GUM; pause
  end
end
end module
```

Alternative Solution

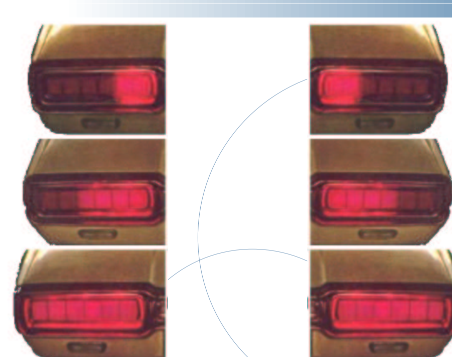
```
loop
  await
    case immediate N do await
      case N do await
        case N do nothing
        case immediate D do nothing
      end
      case immediate D do nothing
    end
    case immediate D do await
      case immediate N do nothing
      case D do nothing
    end
  end;
  emit GUM; pause
end
```

Tail Lights Example

Construct an Esterel program that controls the turn signals of a 1965 Ford Thunderbird.

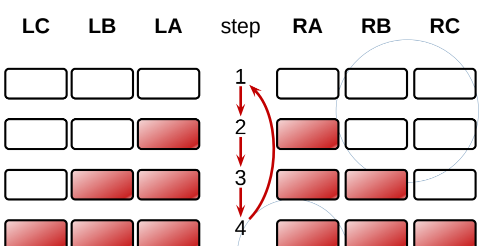
Source: Wakerly, *Digital Design Principles & Practices*, 2ed, 1994, p. 550

Tail Light Behavior



Tail Lights

There are three inputs, LEFT, RIGHT, and HAZ, that initiate the sequences, and six outputs, LA, LB, LC, RA, RB, and RC. The flashing sequence is



A Single Tail Light

```
module Lights:
output A, B, C;

  loop
    emit A; pause;
    emit A; emit B; pause;
    emit A; emit B; emit C; pause;
    pause
  end

end module
```

The T-Bird Controller Interface

```
module Thunderbird :
input LEFT, RIGHT, HAZ;
output LA, LB, LC, RA, RB, RC;

...

end module
```

The T-Bird Controller Body

```
loop
  await
   case immediate HAZ do
     abort
       run Lights[signal LA/A, LB/B, LC/C]
     ||
       run Lights[signal RA/A, RB/B, RC/C]
     when [not HAZ]
   case immediate LEFT do
     abort
       run Lights[signal LA/A, LB/B, LC/C]
     when [not LEFT]
   case immediate RIGHT do
     abort
       run Lights[signal RA/A, RB/B, RC/C]
     when [not RIGHT]
  end
end
```

Comments on the T-Bird

I choose to use Esterel's innate ability to control the execution of processes, producing succinct easy-to-understand source but a somewhat larger executable.

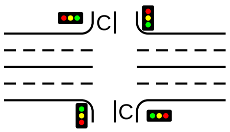
An alternative: Use signals to control the execution of two processes, one for the left lights, one for the right.

A challenge: synchronizing hazards.

Most communication signals can be either level- or edge-sensitive.

Control can be done explicitly, or implicitly through signals.

Traffic-Light Controller Example



This controls a traffic light at the intersection of a busy highway and a farm road. Normally, the highway light is green but if a sensor detects a car on the farm road, the highway light turns yellow then red. The farm road light then turns green until there are no cars or after a long timeout. Then, the farm road light turns yellow then red, and the highway light returns to green. The inputs to the machine are the car sensor **C**, a short timeout signal **S**, and a long timeout signal **L**. The outputs are a timer start signal **R**, and the colors of the highway and farm road lights.

Source: Mead and Conway, *Introduction to VLSI Systems*, 1980, p. 85.

The Traffic Light Controller

```
module Fsm:

input C, L, S;
output R;
output HG, HY, FG, FY;

loop
  emit HG ; emit R; await [C and L];
  emit HY ; emit R; await S;
  emit FG ; emit R; await [not C or L];
  emit FY ; emit R; await S;
end

end module
```

The Traffic Light Controller

```
module Timer:
input R, SEC;
output L, S;

  loop
    weak abort
      await 3 SEC;
      [
         sustain S
      ||
         await 5 SEC;
         sustain L
      ]
    when R;
  end

end module
```

The Traffic Light Controller

```
module TLC:
input C, SEC;
output HG, HY, FG, FY;

signal S, L, S in
  run Fsm
||
  run Timer
end

end module
```