Synchronous Dataflow Programming

CS684: Embedded Systems
Topic 5

Paritosh Pandya

Indian Institute of Technology, Bombay

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Multi-mode controller using switch

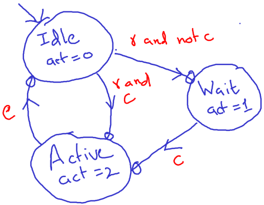
- A node can be in exactly one mode at each clock cycle.
- Equations of the currently active mode are applied.
- Each output and internal variable has exactly one equation in each mode.
- Each mode acts as a name space and clock domain.
  All pre(x) values are stored in a mode local copy. last(x) variables are global and shared between modes.
- reset blocks can be used to reset the equations under specified conditions.

Mixed language for Multi-mode Complex Control

Finite State Automata with data flow equations.

Hybrid Program

- States are modes.
- Each state has an associated set of equations.
- Transitions specify conditions for state (i.e. mode) change.
- Complex control is organized as automata with hierarchy, concurrency and sharing of flows.
- Dataflow and fsm control can be freely mixed and nested.



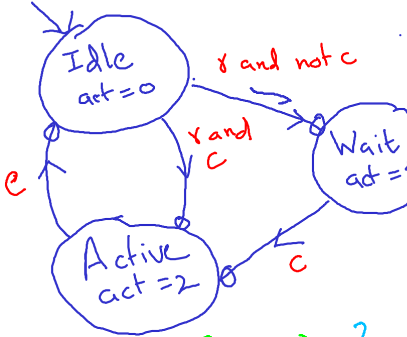
First Example

```
node myautomaton(r,c,e:bool) returns (act:int)
let
     automaton
        state Idle
                do act = 0
        until r and c then Active
            | r and not c then Wait

        state Wait
                do act = 1
        until c then Active

        state Active
                do act = 2
        until e then Idle
    end
tel
```

First Example Diagram



0 1 2 3

st	I	I	I	W	W	W	A	I	I	I	A	...
r	0	0	1	0	1	0	0	0	0	1	0	...
c	0	1	0	0	0	1	0	0	0	1	0	...
e	0	1	0	0	0	0	1	0	0	0	0	...
act	0	0	0	1	1	1	2	0	0	0	2	...
ns	I	I	W	W	W	A	I	I	I	A	A	...

Inputs

Out

Automata under Weak transitions: **until**

Structure of Automaton

- A set of states with transitions between them.
- One set of equations (i.e. mode block) for each state.
- A set of transitions going out of each state (keyword until or unless)
- Each transition has a guard giving condition under which it is taken and target state.

Execution of automaton: In each cycle

- Start State:
- With weak transitions, the start state is the Active state.
- Equations of the active state are applied.
- Guard is evaluated AFTER evaluating the active state equations.
  Guard can refer to variables defined by the equations.
  If guard true transition is taken and next state changed.
- Next State: this is the start state of the next cycle.

State as Mode Block

```
node myautomaton(i : int; c: bool) returns (o: int; stup:bool)
  let
     automaton
       state Up
          do o = 60 -> i+1; stup = true;
       until c continue Down
       state Down
          do o = 150 -> -2 * i; stup = false;
       until c continue Up
     end
  tel
```

ST	U	U	U	U	D	D	D	D	U	U	U	D		...
1 i	4	4	3	3	3	3	3	3	3	3	3	3	3	...
c	0	0	0	1	0	0	0	1	0	0	1	0	0	...
0 o	60	5	4	4	150	−6	−6	−6	4	4	4	−6	−6	...
stup	1	1	1	1	0	0	0	0	1	1	1	0	0	...
NS	U	U	U	D	D	D	D	U	U	U	D			...

Same automaton with reset transitions

```
node myautomaton(i : int; c: bool) returns (o: int; stup:bool)
  let
     automaton
       state Up
          do o = 60 -> i+1; stup = true;
       until c then Down
       state Down
          do o = 150 ~~-> -2~~ * i; stup = false;
       until c then Up
     end
  tel
```

ST								D	U		U	D		...
i	4	4	3	3	3	3	3	3	3	3	3	3	3	...
c	0	0	0	1	0	0	0	1	0	0	1	0	0	...
o	60	5	4	4	150	−6	−6	−6	60	4	4	150	−6	...
stup	1	1	1	1	0	0	0	0	1	1	1	0	0	...
NS								U			D			...

Principles

- A then transition resets the mode block on entry to the state,
- A continue transition enters the states mode block WITHOUT resetting.
- Each state is a mode with its own name space and clock domain.
- pre(x) in a mode refers to the previous value of x when the automaton was in this state.
- last x refers to global variable x shared between states. Its value is value of x in previour cycle (irrespective of the state).

State as Mode block

```
node myautomaton() returns (y:int; stup:bool; v:int)
var last x:int = 2;
let
    y = x;
    automaton
        state Up
                 var w:int;
                 do x = (last x) + 1; stup = true;
                    w = 0 -> pre(w)+1; v=w;
        until  x >= 5 continue Down
        state Down
            var w:int;
            do x = (last x) - 1;  stup = false;
            w = 50 -> pre(w)-2; v=w;
        until x <= 3 continue Up
    end
tel
```

State as Mode block (cont)

```
node myautomaton() returns (y:int; stup:bool; v:int)
var last x:int = 2;
let
    y = x;
    automaton
        state Up
                 var w:int;
                 do x = (last x) + 1; stup = true;
                    w = 0 -> pre(w)+1; v=w;
        until  x >= 5 continue Down
        state Down
            var w:int;
            do x = (last x) - 1;  stup = false;
            w = 50 -> pre(w)-2; v=w;
        until x <= 3 continue Up
    end
tel
```

ST U U U D

y	3	4	5	4	3	4	5	4	3	4	...
stup	1	1	1	0	0	1	1	0	0	1	...
v	0	1	2	50	48	3	4	46	44	5	...

NS U U D