

Synchronous Dataflow Programming

CS684: Embedded Systems

Topic 5

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Multi-mode controller using switch

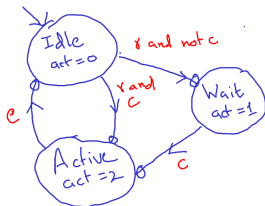
- A node can be in exactly one mode at each clock cycle.
- Equations of the currently active mode are applied.
- Each output and internal variable has exactly one equation in each mode.
- Each mode acts as a name space and clock domain.
All $\text{pre}(x)$ values are stored in a mode local copy. $\text{last}(x)$ 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.



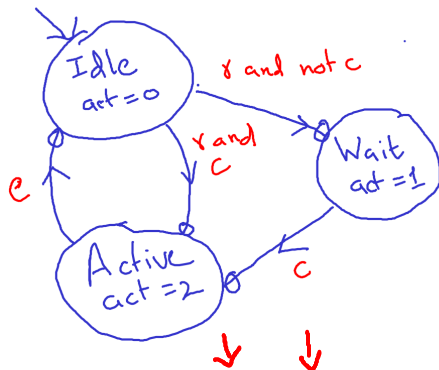
First Example

```
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



state = active

st	/	/	/	W	W	W	A	/	/	/	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	/	/	W	W	W	A	/	/	/	A	A	...

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
```

Resume

ST	U	U	U	U	D	D	D	D	U					...
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	<u>4</u>	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						...

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
```

reset

ST														...
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	<u>60</u>	4	4	<u>150</u>	-6	...
stup	1	1	1	1	0	0	0	0	1	1	1	0	0	...
NS														...

- A **then** transition resets the mode block on entry to the state,
- A **continue** transition enters the states mode block WITHOUT resetting. *resume*
- 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 previous 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)

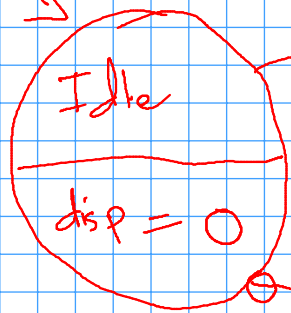
```
node myautomaton() returns (y:int; stup:bool; v:int)
var last x:int = 2;
let
  y = x;
  automaton
    state Up
      var w:int;
      do x = (last x) + 1; stup = true;
        w = 0 -> pre(w)+1; v=w;
    until x >= 5 continue Down
    state Down
      var w:int;
      do x = (last x) - 1; stup =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

ST UUDDDU

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	...

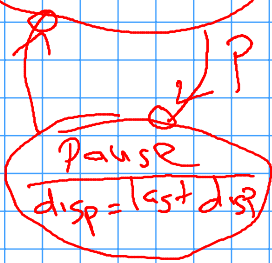
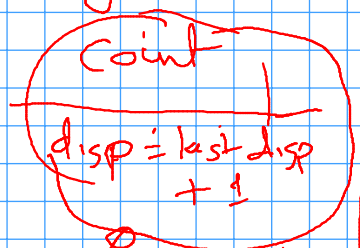
NS UUDDDU

last disp = cnt = 0;



R

Counting



R

P

node stopwatch(p, q: bool) returns (disp: val)
Automaton sec: bool

state Idle do

disp = 0

until $\&$ then Counting

state Counting do

automat

state Count.

until p then —

state Pause

end until. p then —

until $\&$ then Idle

end

Concurrent Automata

```
node myautomaton () returns (ping,pong : bool)
let
  automaton -- A_ping
    state S1
      do ping = true
      until true then S2
    state S2
      do ping = false
      until pong then S1
  end;

  automaton -- A_pong
    state S1
      do pong = false
      until ping then S2
    state S2
      do pong = true
      until true then S1
  end
tel
```

global
state

ST $(S_1, S_1) (S_2, S_2)$

ping	1	0	1	0	1	...
pong	0	1	0	1	0	...

NS $(S_2, S_2) (S_1, S_1)$

Strong Transitions: Example

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

ST	...								
AS	...								
i	4	4	4	4	4	4	4	4	...
c	0	0	0	1	0	0	1	0	...
o	60	5	5	150	-8	-8	60	5	...
stup	1	1	1	0	0	0	1	1	...
NS	...								

Understanding strong transitions

In each cycle,

- Start State:
- guard is evaluated BEFORE any equations.
Guard cannot refer to current value of equation output.
- If the guard is true, ACTIVE STATE is the target state of unless.
otherwise it remains the start state.
- equations of ACTIVE STATE are applied.
- Now until transition of the active state (if any) is applied.
- No successive unless is applied. At most one unless followed by one until.

Weak and Strong Transitions: Example

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

ST	...											
AS	...											
i	4	4	4	4	4	4	4	4	4	4	4	...
c	0	0	0	1	0	0	0	1	1	0	0	...
o	60	5	5	150	60	5	5	150	150	60	5	...
stup	1	1	1	0	1	1	1	0	0	1	1	...
NS	...											