Synchronous Dataflow Programming

CS684: Embedded Systems

Topic 5

Paritosh Pandya

Indian Institute of Technology, Bombay

February 16, 2021

Summary

Multi-mode controller as FSA + Dataflow Equations.

- Automaton can be in one active state at each cycle.
- Each state is a mode with associated set of equations. Equations of the active state are applied.
- Each state is a name space and clock domain. $pre(x)$ refers to mode local copy of x. Construct $last(x)$ allows values to be shared between modes.
- Each state has outgoing until (or weak) transitions. After executing the equations of the active state, the guards of its until transitions are evaluated to decide the next state.
- Thus, weak state transition takes effect from the next cycle.
- In a continue type transition, the state change occurs without resetting the equations of the target state.
- In a then type transition, the state change occurs with resetting of the equations of the target state.

Structure of a Node with Concurrent Automata

```
node myautomaton () returns (y:int)
let
    y = x + z;

    automaton --autA
      state S1 do x = 10 -> pre(x)+1;
          ...
    end

    automaton --autB
      state T1 do z = 20;
          ...
      end
tel
```

Equations and automata all execute in parallel in lock-step (synchronous) manner.

Concurrent Automata: Example

```
node myautomaton () returns (ping,pong : bool)
let
automaton  -- A_ping
    state S1a
        do   ping = true
    until true then S2a
    state S2a
        do   ping = false
    until pong then S1a
end;
```

```
automaton -- A_pong
    state S1b
        do   pong = false
    until ping then S2b
    state S2b
        do   pong = true
    until  true then S1b
end
tel
```

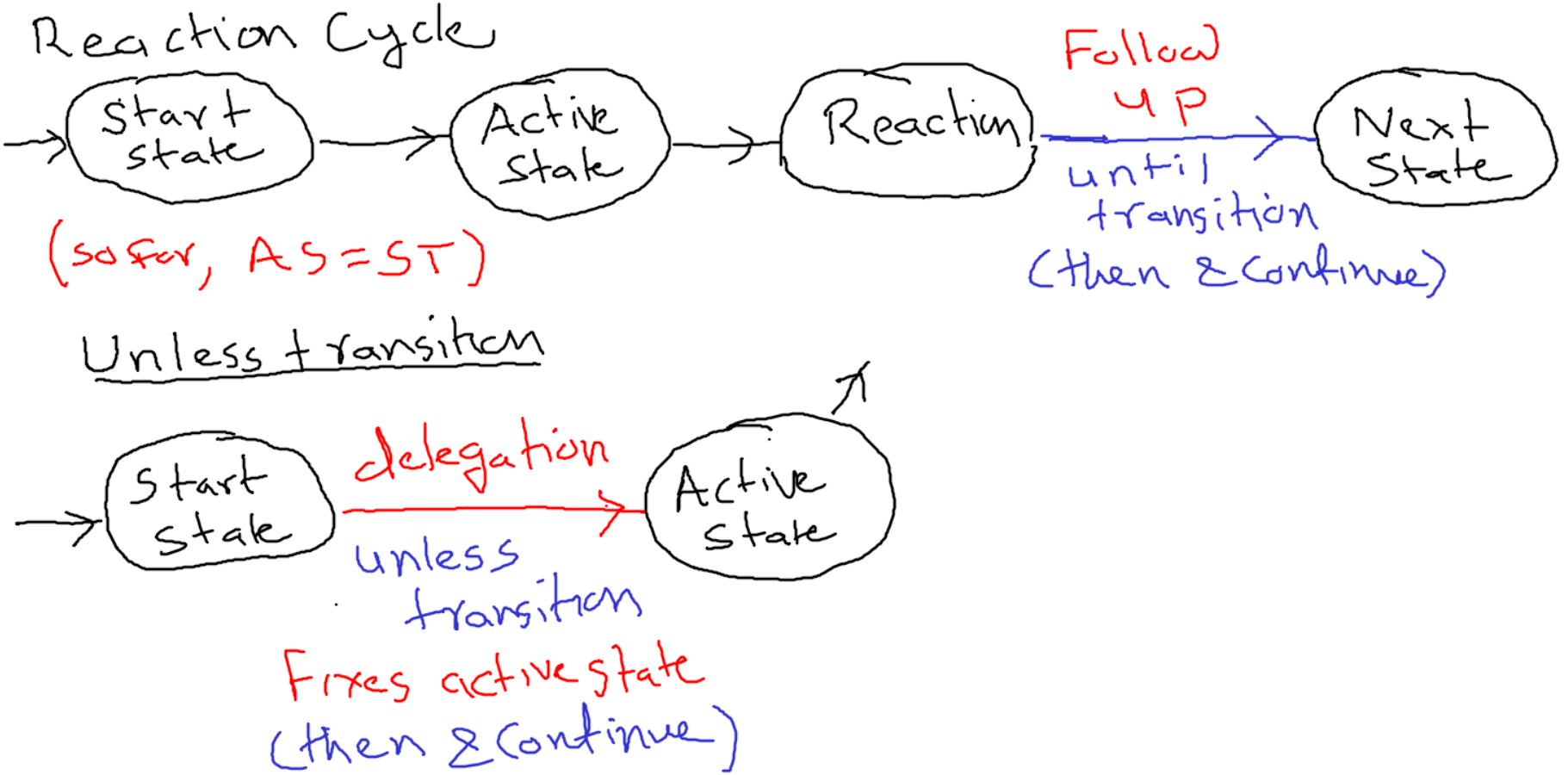
ST	$(S1a, S1b)$	$(S2a, S2b)$	$(S1a, S1b)$	$(S2a, S2b)$	$(S1a, S1b)$	...
ping	1	0	1	0	1	...
pong	0	1	0	1	0	...
NS	$(S2a, S2b)$	$(S1a, S1b)$	$(S2a, S2b)$	$(S1a, S1b)$	$(S2a, S2b)$	...

Automaton with until and reset transition (Revision)

```
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	*U*	*U*	*U*	*U*	*D*	*D*	*D*	*D*	*U*	*U*	*U*	*D*	*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*	*U*	*U*	*D*	*D*	*D*	*D*	*U*	*U*	*U*	*D*	*D*	*D*	...

Reaction Cycle of an Automaton



Unless Transitions: Motivation

Unless transitions are also called strong transitions.

- They allow delegation of reacting in current cycle to another state.
- A state can have one or more unless transitions.
- Guard of an unless transition is evaluated before looking at the equations (i.e. before reacting).
  Hence, guard cannot use current values of equations.
- If guard is true, control moves to the target state in the same cycle.
- Thus, target state becomes the active state. Its equations are applied.
- If the guards of all unless transitions are false, the current state remains the active state.
- After the reaction, the until transitions of the active state decides the next state.
- At most one delegation is allowed per cycle.

Reaction Cycle

- Start State
- Delegation Apply unless transition to determine the active state of the current cycle.
- Reaction Equations of the active state are applied to compute output from input.
- Followup AFTER the reaction, apply the until transition of the active state:
  Guard of each until transition is evaluated.
  Guard can refer to outputs the equations.
  If guard is true the transition is taken and next state is changed to target state.
- Next State: this is the start state of the next cycle.
- For both unless and until transitions, the equations are reset for **then** type transition. They are not reset for a **continue** type transition.

Unless 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
  tel
```

ST	*U*	*U*	*U*	*U*	*D*	*D*	*D*	*U*	...
AS	*U*	*U*	*U*	*D*	*D*	*D*	*U*	*U*	...
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	*U*	*U*	*U*	*D*	*D*	*D*	*U*	*U*	...

Mixing unless and until 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
  tel
```

ST	U	U	U	U	U	U	U	U	U	U	U	...
AS	U	U	U	D	U	U	U	D	D	U	U	...
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	U	U	U	U	U	U	U	U	U	U	U	...