

Symbolic Model Checking

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Solution to Exercise 2 (An Elevator Controller)

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-- AN ELEVATOR CONTROLLER                                     --
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-- This SMV program describes an elevator system for a 4-floors building.
-- It includes modules both for the physical system (reservation buttons,
-- cabin, door), and for the controller.

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-- BUTTON                                                    --
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-- For each floor there is a button to request service, that can be
-- pressed. A pressed button stays pressed unless reset by the
-- controller. A button that is not pressed can become pressed
-- nondeterministically.

MODULE Button(reset)
  VAR
    pressed : boolean;
  ASSIGN
    init(pressed) := 0;
    next(pressed) :=
      case
        pressed & reset   : 0;
        pressed & !reset  : 1;
        !pressed          : {0,1};
      esac;

  -- REQ: The controller must not resets a button that is not pressed.
  INVARSPEC (reset -> pressed)

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-- CABIN                                                    --
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-- The cabin can be at any floor between 1 and 4. It is equipped with an
-- engine that has a direction of motion, that can be either standing, up
-- or down. The engine can receive one of the following commands: nop, in
-- which case it does not change status; stop, in which case it becomes
-- standing; up (down), in which case it goes up (down).
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MODULE Cabin(move_cmd)
  VAR
    floor      : { 1,2,3,4 };
    direction  : { standing, moving_up, moving_down };

  ASSIGN
    init(direction) := standing;
    next(direction) :=
      case
        move_cmd = stop      : standing;
        move_cmd = move_up   : moving_up;
        move_cmd = move_down : moving_down;
        move_cmd = nop       : direction;
      esac;

    next(floor) :=
      case
        next(direction) = standing : floor;
        next(direction) = moving_up : case
          floor = 4 : 4;
          1         : floor + 1;
        esac;
        next(direction) = moving_down : case
          floor = 1 : 1;
          1         : floor - 1;
        esac;
      esac;

    -- REQ: The controller can issue a stop command only if the direction
    --       is up or down.
    INVARSPEC (move_cmd = stop -> direction in {moving_up,moving_down})

    -- REQ: The controller can issue a move command only if the
    --       direction is standing.
    INVARSPEC (move_cmd in {move_up,move_down} -> direction = standing)

    -- REQ: The cabin can move up only if the floor is not 4.
    SPEC AG (floor = 4 -> AX(direction != moving_up))

    -- REQ: The cabin can move down only if the floor is not 1.
    SPEC AG (floor = 1 -> AX(direction != moving_down))

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    -- DOOR
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    -- The cabin is also equipped with a door, that can be either open
    -- or closed. The door can receive either open, close or nop commands
    -- from the controller, and it responds opening, closing, or
    -- preserving the current state.

MODULE Door(door_cmd)
  VAR
    status : { open, closed };

  ASSIGN
    next(status) :=
      case
        door_cmd = open      : open;
        door_cmd = close     : closed;
        door_cmd = nop       : status;
      esac;

```

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-- REQ: The controller can issue an open command only if the door is closed.
INVARSPEC (door_cmd = open  ->  status = closed)

-- REQ: The controller can issue a close command only if the door is open.
INVARSPEC (door_cmd = close ->  status = open)

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-- CONTROLLER
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-- The controller takes in input (as sensory signals) the floor and the
-- direction of motion of the cabin, the status of the door, and the
-- status of the four buttons. It decides the controls to the engine, to
-- the door and to the buttons.

MODULE CTRL(floor, dir, door, pressed_1, pressed_2, pressed_3, pressed_4)
VAR
  move_cmd : {move_up, move_down, stop, nop};
  door_cmd : {open, close, nop};
  reset_1  : boolean;
  reset_2  : boolean;
  reset_3  : boolean;
  reset_4  : boolean;

-- Button N is reset only if it is pressed, we are at floor N, and
-- the door is open.
ASSIGN
  reset_1 := (pressed_1 & floor = 1 & door = open);
  reset_2 := (pressed_2 & floor = 2 & door = open);
  reset_3 := (pressed_3 & floor = 3 & door = open);
  reset_4 := (pressed_4 & floor = 4 & door = open);

-- Check whether there are pending requests at the current floor,
-- at a higher floor, and at a lower floor.
DEFINE
  pending_here := (floor = 1 & pressed_1) | (floor = 2 & pressed_2) |
                 (floor = 3 & pressed_3) | (floor = 4 & pressed_4) ;

  pending_up   := (floor = 1 & ( pressed_2 | pressed_3 | pressed_4 )) |
                 (floor = 2 & (           pressed_3 | pressed_4 )) |
                 (floor = 3 & (           pressed_4 )) ;

  pending_down := (floor = 4 & ( pressed_1 | pressed_2 | pressed_3 )) |
                 (floor = 3 & ( pressed_1 | pressed_2           )) |
                 (floor = 2 & ( pressed_1           )) ;

-- * If the cabin is moving, do not send commands to the door.
-- * If there is a pending request at the current floor and
--   the door is closed, open it.
-- * If there are pending requests at different floors and the
--   door is open, close it.
-- * Otherwise, do not send commands to the door.
ASSIGN
  door_cmd :=
  case
    dir != standing           : nop;
    pending_here & door = closed : open;
    pending_up   & door = open   : close;
    pending_down & door = open   : close;
    1               : nop;
  esac;

```

```

-- Variable "last_dir" records the last movement direction of the cabin.
VAR
  last_dir : {moving_up,moving_down};
ASSIGN
  next(last_dir) :=
    case
      dir = standing : last_dir;
      1                : dir;
    esac;

-- * If the door is open, do not send move commands to the cabin.
-- * If there is a pending request at the current floor
--   and the cabin is moving, stop it.
-- * If there are pending requests both at higher and at lower floors,
--   keep moving in "last_dir".
-- * If there are pending requests at higher (lower) floors,
--   move up (down).
-- * Otherwise, do not send commands to the cabin.
ASSIGN
  move_cmd :=
    case
      door = open          : nop;
      pending_here        : case
        dir != standing   : stop;
        1                  : nop;
      esac;
      pending_up & pending_down : case
        dir != standing   : nop;
        last_dir = moving_up : move_up;
        last_dir = moving_down : move_down;
      esac;
      pending_up          : case
        dir != standing   : nop;
        1                  : move_up;
      esac;
      pending_down        : case
        dir != standing   : nop;
        1                  : move_down;
      esac;
      1                    : nop;
    esac;

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-- MAIN
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-- The main module shows the connection between modules.

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MODULE main
VAR
  cabin : Cabin(ctrl.move_cmd);
  door  : Door(ctrl.door_cmd);
  button_1 : Button(ctrl.reset_1);
  button_2 : Button(ctrl.reset_2);
  button_3 : Button(ctrl.reset_3);
  button_4 : Button(ctrl.reset_4);
  ctrl : CTRL(cabin.floor, cabin.direction, door.status,
             button_1.pressed, button_2.pressed,
             button_3.pressed, button_4.pressed);

```

-- REQUIREMENTS --

-- The controller must satisfy the following requirements.

-- REQ: No button can reach a state where it remains pressed forever.

SPEC AG AF ! button_1.pressed

SPEC AG AF ! button_2.pressed

SPEC AG AF ! button_3.pressed

SPEC AG AF ! button_4.pressed

-- REQ: No pressed button can be reset until the cabin stops at the
-- corresponding floor and opens the door.

SPEC AG (button_1.pressed ->

 A [button_1.pressed U (cabin.floor = 1 & door.status = open)])

SPEC AG (button_2.pressed ->

 A [button_2.pressed U (cabin.floor = 2 & door.status = open)])

SPEC AG (button_3.pressed ->

 A [button_3.pressed U (cabin.floor = 3 & door.status = open)])

SPEC AG (button_4.pressed ->

 A [button_4.pressed U (cabin.floor = 4 & door.status = open)])

-- REQ: A button must be reset as soon as the cabin stops at the
-- corresponding floor with the door open.

SPEC AG ((button_1.pressed & cabin.floor = 1 & door.status = open) ->

 AX ! button_1.pressed)

SPEC AG ((button_2.pressed & cabin.floor = 2 & door.status = open) ->

 AX ! button_2.pressed)

SPEC AG ((button_3.pressed & cabin.floor = 3 & door.status = open) ->

 AX ! button_3.pressed)

SPEC AG ((button_4.pressed & cabin.floor = 4 & door.status = open) ->

 AX ! button_4.pressed)

-- REQ: The cabin can move only when the door is closed.

INVARSPEC (door.status = open -> cabin.direction = standing)

-- REQ: If no button is pressed, the controller must issue no commands

-- and the cabin must be standing.

INVARSPEC (((! button_1.pressed) & (! button_2.pressed) &

 (! button_3.pressed) & (! button_4.pressed))

 -> (ctrl.door_cmd = nop & ctrl.move_cmd = nop))
