**CS 5103 – PROJECT 2**

**Elevator Control System**

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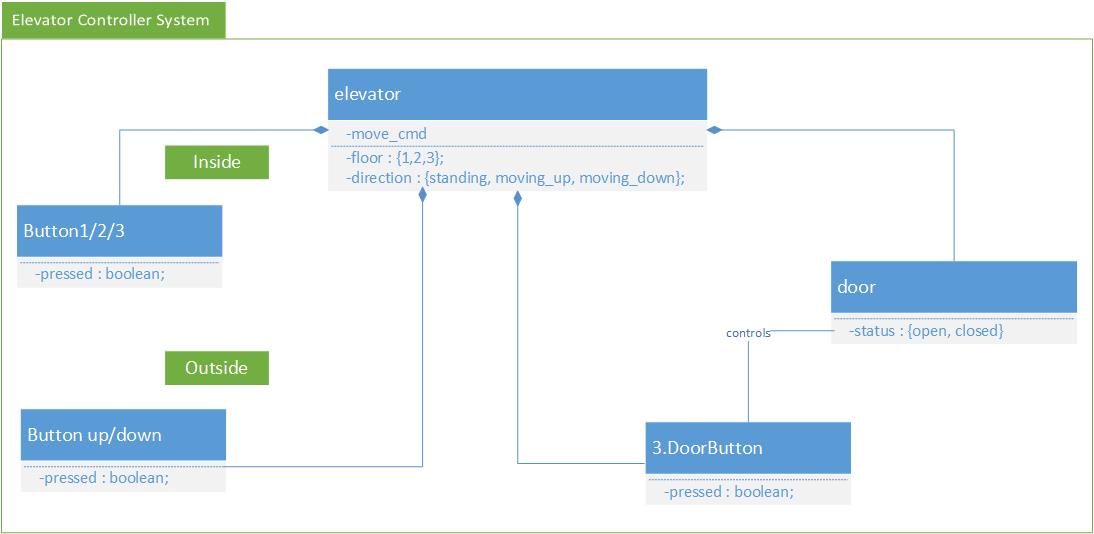
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# **1. Design of the system**

## 1.1 Variables of the elevator system

The basic function of the elevator is to move from bottom floor to the top floor. There are floor buttons which sends the floor request, whereas up and down buttons tells the moving direction of the elevator when users are on the floor.

It is assumed that button1/2/3, button up/down, door button are three main variables of the elevator. Cabin has floor and direction, which can be changed with the move command. Door has open and closed status, which can be changed by the door command.



### 1.1.1 floor button

There are buttons inside the elevator which sends floor request to elevator.

There are also the request buttons for each floor inside elevator. Its possible state is Boolean which means its status can be pressed or not pressed.

VAR

button1: boolean;

button2: boolean;

button3: boolean;



### 1.1.2 up and down button

There are request buttons for each floor outside elevator from floor 1 to floor 3. Its possible state can be pressed or not pressed.

VAR

upF1: boolean;

upF2: boolean;

downF2: boolean;

downF3: boolean;



### 1.1.3 door button

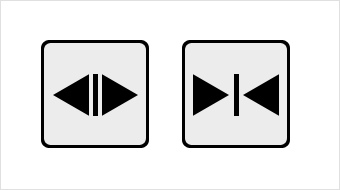
There are request buttons to open or close the door. Its possible state can be pressed or not pressed.

When pressed by users either from inside or outside, the state will transfer to be pressed.

VAR

buttonOpen: boolean;

buttonClose: boolean;



### 1.1.4 elevator

The elevator cabin can reach from floor 1 to 3, the first variable should be floor.

Each floor has initial direction of standing and other two possible directions of moving up and down, which is also the second variable.

The elevator receives command from elevator controller to stop, go up and go down.

The door or elevator has two status of open and close.

VAR

move\_cmd : {stop, move\_up, move\_down, nop};

floor : {1,2,3};

direction : {standing, moving\_up, moving\_down};

door : {open, closed};

## 1.2 Assignment of the elevator system

The controller inside the elevator sends move command and door open/close command to elevator cabin. It is necessary to define variable of them, and how the status change by using ASSIGN.

### 1.2.1 door

The door status of the elevator cabin can be open or closed. After it receives the door command, it will change its status.

Never send any command during the period when the cabin is moving.

If the cabin is stopped and the door is closed, when open door button is pressed, change the door status to open. Or if the door is open and close door button is pressed, change the door status to closed.

If the pending request is up or down and the door is open, change the door status to closed to ensure security during the movement.

Otherwise do nothing.

VAR

doorstatus : {open, closed};

ASSIGN

next(door) := case

direction != standing : closed;

move\_cmd = stop & door = closed & buttonOpen : open;

move\_cmd = stop & door = open & buttonClose : closed;

(move\_cmd = move\_up | move\_cmd = move\_down) & door = open : closed;

TRUE:closed;

esac;

### 1.2.2 Elevator

The direction of elevator is related to move\_cmd. The elevator receives command from elevator controller to stop, go up and go down. Then the direction will change accordingly.

ASSIGN

next(direction) := case

move\_cmd = stop : standing;

move\_cmd = move\_up : moving\_up;

move\_cmd = move\_down : moving\_down;

move\_cmd = nop : direction;

esac;

Two kinds of buttons change the value of floor. If button1 is pressed inside the cabin or any user press the upF1 button on the first floor, the floor will eventually go to floor1.

If button2 is pressed inside the cabin or any user press the either upF2 or downF2 button on the second floor, the floor will eventually go to floor2.

If button3 is pressed inside the cabin or any user press the downF3 button on the third floor, the floor will eventually go to floor3.

ASSIGN

next(floor) := case

button1 | upF1 : 1;

button2 | upF2 | downF2 : 2;

button3 | downF3 : 3;

TRUE : floor;

esac;

It is the most complex command generated from controller. Move command determined by which floor the user is on and two kind of buttons.

We assume a user is on any floor from 1 to 3. If the corresponding floor button is pressed, that is press button1 on floor 1, the move command should be stop.

If the user is on floor 1, and button2 or button3 is pressed which mean he will go up, or any of upF2 | downF2 | downF3 is pressed which mean outside user give go up command to elevator, the move\_cmd will eventually come to move\_up. If on floor2, any of button3 | downF3 is pressed, move\_cmd will come to move\_up. On floor 3, never move up.

If the user is on floor 3, and button1 or button2 is pressed which mean he will go down, or any of upF2 | downF2 | upF1 is pressed which mean outside user give go down command to elevator, the move\_cmd will eventually come to move\_down. If on floor2, any of button1 | downF1 is pressed, move\_cmd will come to move\_down. On floor 1, never move down.

ASSIGN

next(move\_cmd) := case

door = open : nop;

(floor = 1 & button1) | (floor = 2 & button2) | (floor = 3 & button3) : stop;

(floor = 1 & ( button2 | button3 | upF2 | downF2 | downF3)) | (floor = 2 & (button3 | downF3)) : move\_up;

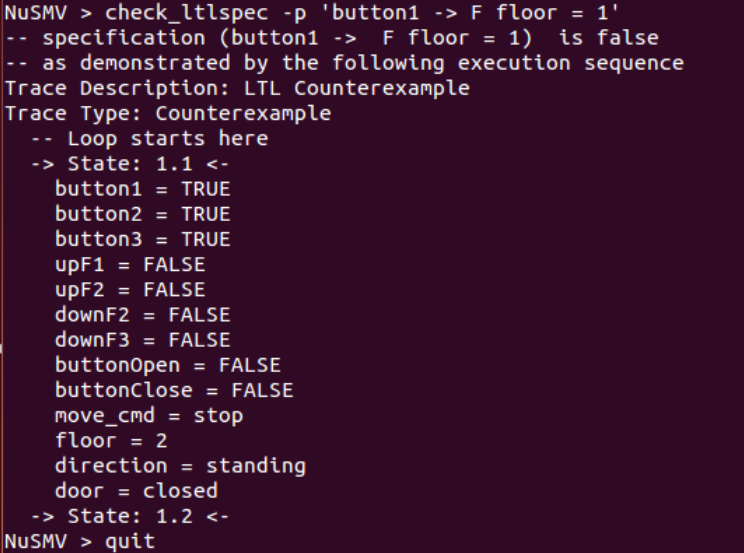
(floor = 3 & ( button1 | button2 | upF2 | downF2 | upF1)) | (floor = 2 & (button1 | upF1)) : move\_down;

TRUE : nop;

esac;

### 1.2.3 Modification

Whenever we test the G(button1 -> F floor = 1) logic specification, it will give us counterexample as follows. It means when button1 and button2 and button3 are pressed at the same time, the elevator never move since the floor command is unclear. So we define limitation to those three buttons that only one of them can be pressed.



ASSIGN

next(button1):= case

button1 = TRUE & button2 = FALSE & button3 = FALSE : TRUE;

TRUE : FALSE;

esac;

next(button2):= case

button1 = FALSE & button2 = TRUE & button3 = FALSE : TRUE;

TRUE : FALSE;

esac;

next(button3):= case

button1 = FALSE & button2 = FALSE & button3 = TRUE : TRUE;

TRUE : FALSE;

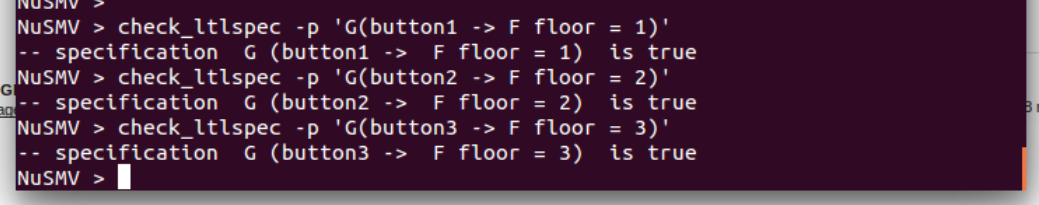
esac;

# **2. Verification Results**

## 2.1 Basic model checking

### 2.1.1 Requests to be delivered to a particular floor are eventually serviced

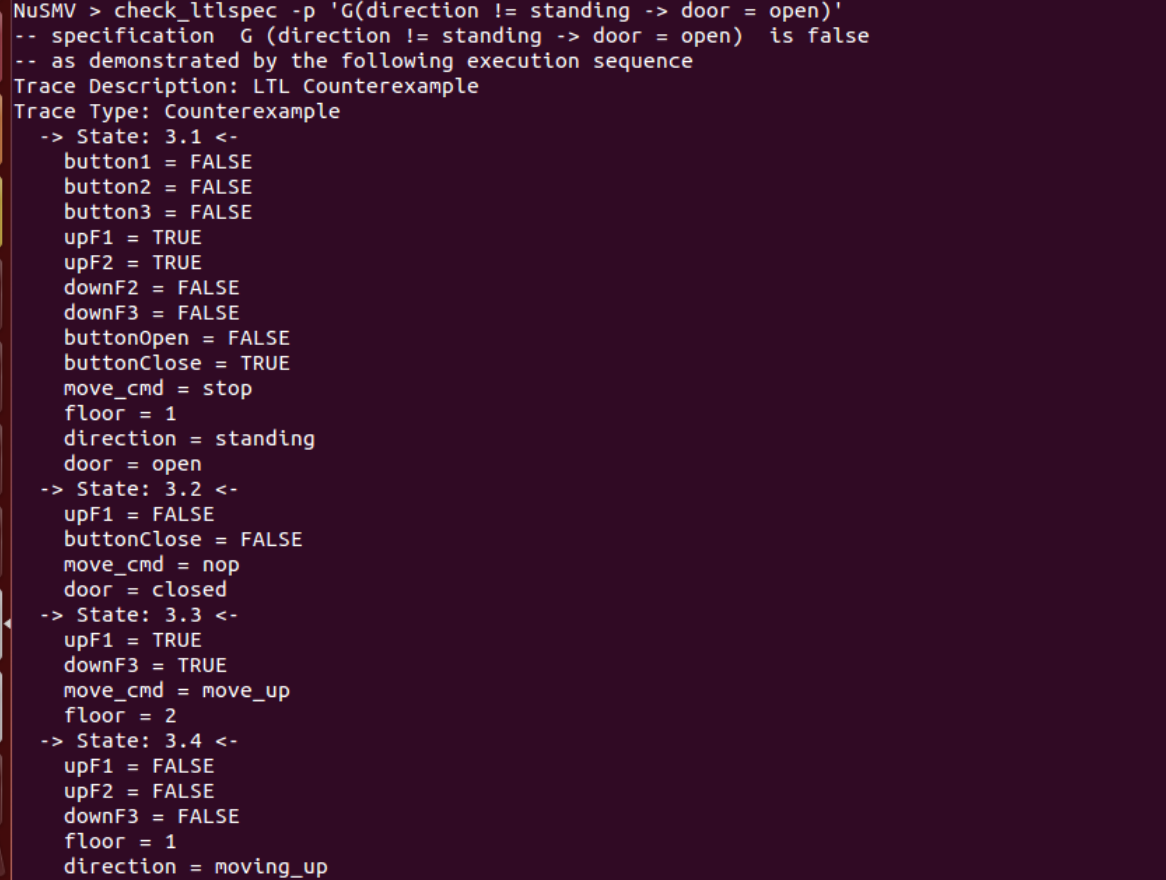
Whenever the user press floor button, the future status could be the corresponding floor. That means the request of the user has response.

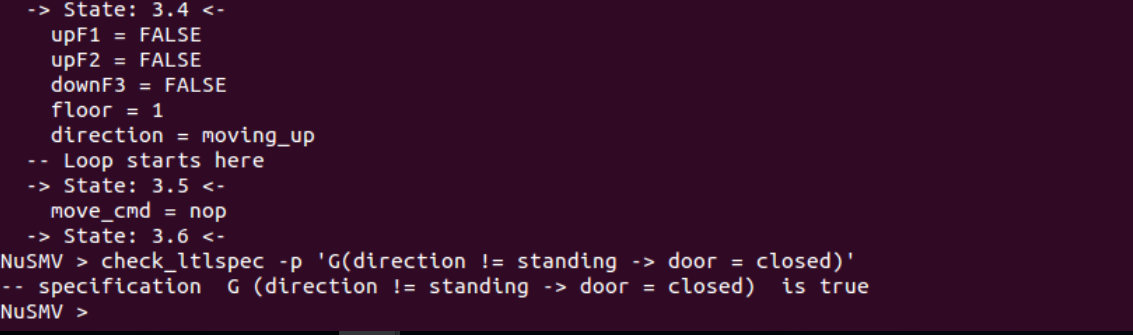


### 2.1.2 The elevator never moves with its doors open

Check the logic specification ‘G (direction != standing -> door = open)’, the result is false. It gives us several counterexample which illustrate the door can’t be open when the cabin is moving.

Check the logic specification ‘G (direction != standing -> door = closed)’, the result is true.



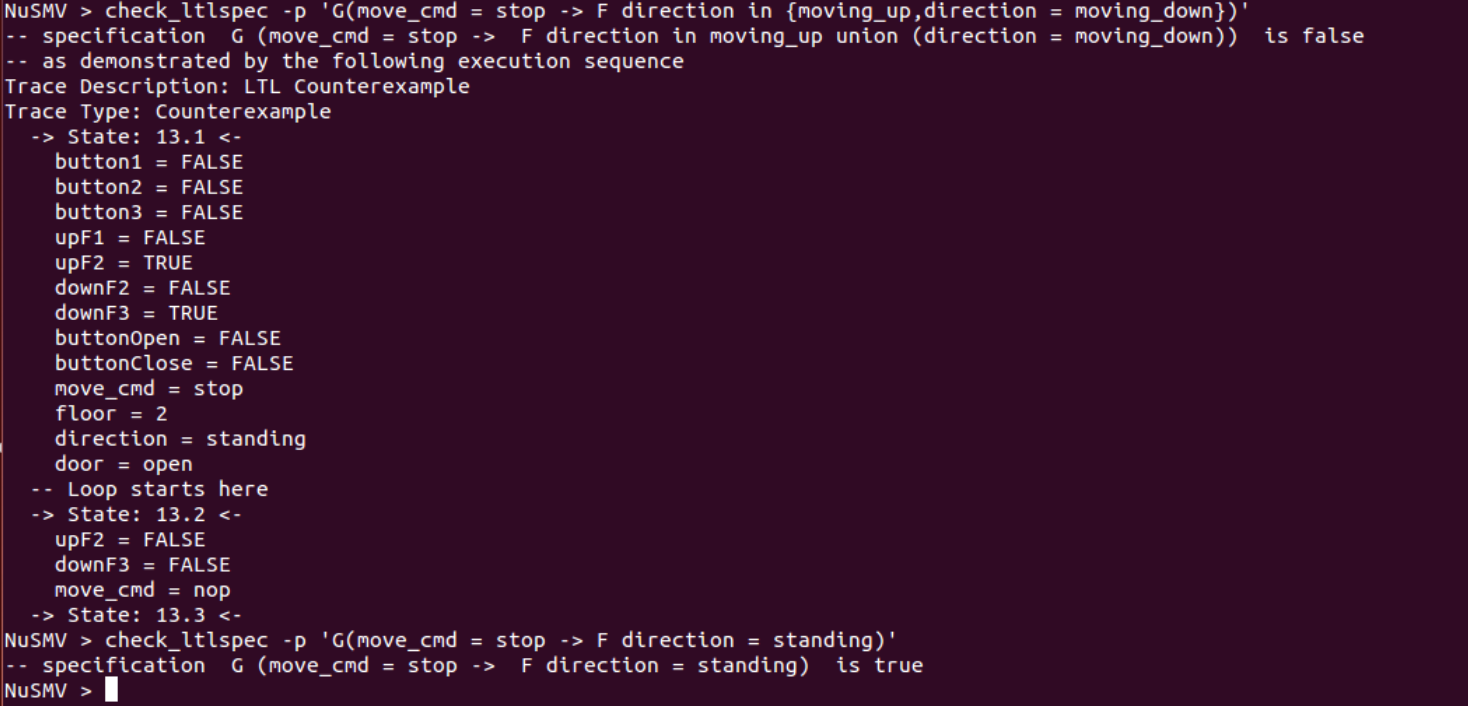


## 2.2 model checking for other variables

### 2.2.1 Direction follows the move command

Check the logic specification ‘G (move\_cmd = stop -> F direction in {moving\_up, moving\_down})’, the result is false, since there is possibility that the cabin does not move.

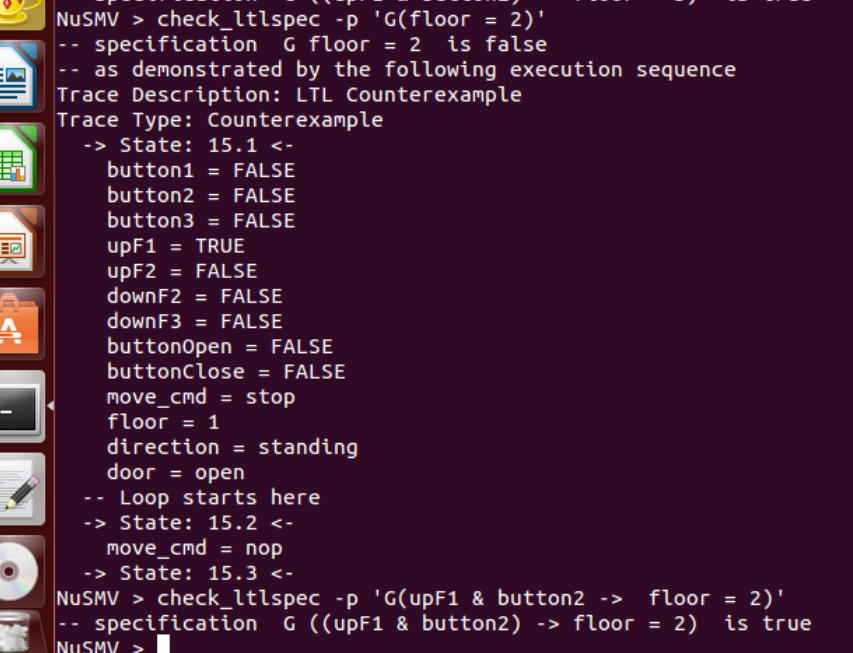
Check the logic specification ‘G (move\_cmd = stop -> F direction = standing)’, the result is true. After the cabin received the stop command, its status will change to standing.



### 2.2.2 Up and down button will send the elevator to that floor

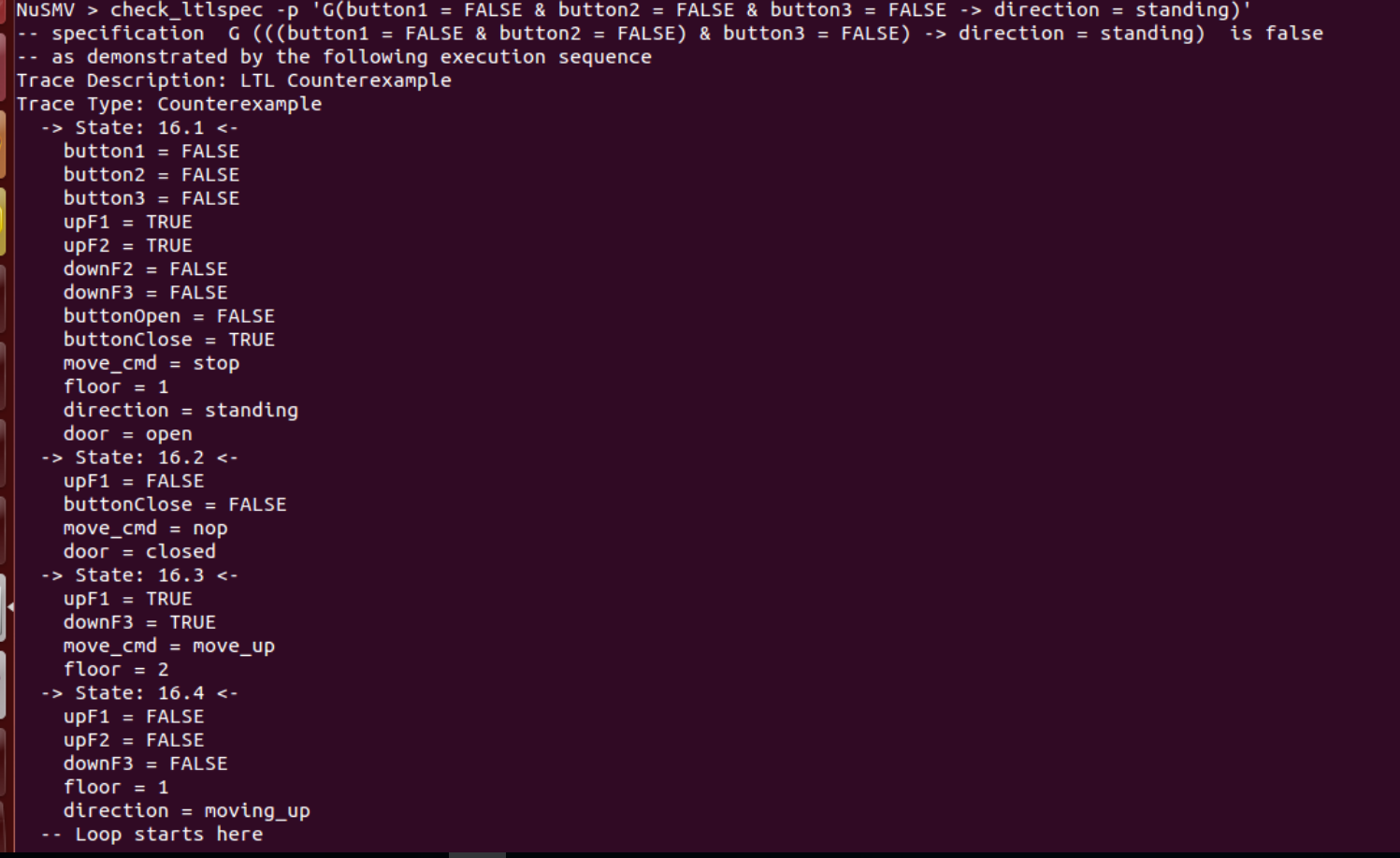
Check G(floor = 2) will get false result, since under some condition the elevator will not go to floor 2. But when the upF2 is pressed, the future result of floor = 2 can be true.

Suppose a use enter the elevator on floor 1 and someone press upF2 on second floor, the elevator will eventually go to floor 2.



### 2.2.3 The elevator can still move when no floor button pressed

Even if neither of button1, button2, button3 is impressed, the elevator can still move since someone has pressed the up and down button to send move command to the elevator.



# **3. Experience Gained**

## 3.1 Advantage

The basic This project of elevator control system proved to be a good learning experience in NuSMV. During the project, we are able to know the abilities of NuSMV. It is used to create the model for a software system and do model checking by writing temporal logic specification statements.

The key point of using NuSMV is to define variables and how status changes. For variables, like for elevator control system, we need to draw a diagram to make sure which properties should be refined as a variable. Then we should judge transition relation, that is the transition of status of each variable. We can see clearly the result of the logic specification from NuSMV module. If it is not true, we can see all the counterexample listed.

## 3.2 Disdvantage

When there’s too many variables, it is difficult to tell the initial status. Also the simulate command will not work.