COL719
Synthesis of Digital Systems

Assignment 1; Part 3

Integrating Display, Sensor and Adaptive Units

Ishvik Kumar Singh
2018EE10616

Corrections in Part 1

- **Correction 1**
  Error
  If an 'emergency' interrupt occurred during green signal, the green signal was aborted, followed by an emergency period of 10 sec and then the green signal was resumed and continued for the time remaining (time left for green signal when it was aborted).

  Correction
  Now, when an 'emergency' interrupt occurs during a green signal, the green signal is aborted right away, following by the full duration of orange signal and then an 'emergency' period occurs for 10 sec.

  Now the 'emergency' and 'pedestrian' interrupts are handled in the following way:
  1. If an 'emergency' interrupt and 'pedestrian' interrupt both occur during green/orange signal, 'emergency' is given order preference over 'pedestrian'. That is, once the orange period is over, first the 'emergency' period is observed, followed by 'pedestrian' period.
  2. 'emergency' and 'pedestrian' interrupts are only accepted during green or orange signals. If they occur during 'emergency' period or 'pedestrian' period, they are ignored.
  3. Multiple 'emergency'/ 'pedestrian' interrupts during green/orange signal will only result in a single 'emergency'/ 'pedestrian' period.

- **Correction 2**
  Error
  The seven-segment display unit didn't display the light color.

  Correction
  Now the seven-segment display unit has an additional input port for the light color from the controller. Now, the display unit consists of three seven-segment displays. Two for timers and one for light color.

Apart from the above changes, the display timer unit now also approximates the T_{g_i} values in the units of τ. To maintain the invariant only T_{g_N}, T_{g_E}, and T_{g_S} are estimated, T_{g_W} is calculated as follows:

$$T_{g_W} = T_{cyc} - 4 * T_{or} - T_{g_N} - T_{g_E} - T_{g_S}$$

NOTE: The source code of 'part 1' is rewritten. Please refer to the file attached with 'part 3' of the assignment. Now all timers and signal colors are maintained by a single process. Earlier there were four processes for maintaining the timers of each direction and one process maintaining the signal colors. These have been combined into a single process now. Also process 'counter' have been removed. The remaining processes work as usual.

NOTE: All seven-segment displays are assumed to be active-low.

Corrections in Part 2

- **Correction 1**
  Error
  In the adaptive unit, T_{g_i}'s were evaluated at the end of cycles of each direction.

Correction

Now, T_{g_i}'s are evaluated only at the end of the cycle of west direction. This required changing the sensitivity list of each of the processes that evaluated T_{g_i}. The processes are now sensitive only to 'average number of vehicles in west direction'.

NOTE: The source code of 'part 2' has been modified. Please refer to the file attached with 'part 3' of the assignment.

Design Decisions and Assumptions: Part 3

All the units – display, sensor, and adaptive units, are combined using the entity 'system'. The architecture of the entity consists of components of each of these units. Namely, there are 4 sensor units (one for each direction), 4 color/timer display units (one for each direction), 1 controller for timer and signal color, and 1 adaptive unit.

The input ports are as follows: clock (clk), emergency bit (emgBit), pedestrian bit (pedBit), 4 ports for sensor readings of number of vehicles from each direction (N1, N2, N3, N4). There are 12 output ports, i.e., 4 sets of 3 output ports. Each set is for a single direction and represents the output of the display unit. In each set there are 3 bit vector outputs – one denoting the LSB of the timer (in hexadecimal), the other denoting the MSB of the timer (in hexadecimal) and the third one denoting the color of the signal.

The process flow is as follows:

1. As soon as the clock starts, the traffic system starts. The timer/signal controller starts, and the remaining time and signal color starts to display on each of the seven-segment display units. The controller also ensures that all the T_{g_i} are multiples of τ.
2. The sensor unit in a particular direction receives signal color in that direction from the timer/signal controller. Every time the signal color changes from red to green, the sensor unit reads in the number of vehicles. These values are accumulated over k cycles in each direction and then averaged.
3. The average values from sensor units go to the adaptive unit which computes the new T_{g_i} values. The processes in adaptive unit which compute T_{g_i} values are sensitive only to the average value in west direction. Therefore, the new T_{g_i} values are computed only when k cycles in the west direction end. These newly computed T_{g_i} values are sent to the timer/signal controller. They come into effect from the $(k+1)^{th}$ cycle for each direction.

Following are the generic parameters and their initialized values:

1. Cycle Time, Tcyc - 200 sec
2. Orange Time, Tor - 10 sec
3. β, beta - 1
4. τ, tau – 10
5. k - 50

Based on the above values of cycle time and orange time, the initial value of all T_{g_i}'s is 40 sec.

NOTE: The clock frequency is assumed to be 1 Hz

Simulations

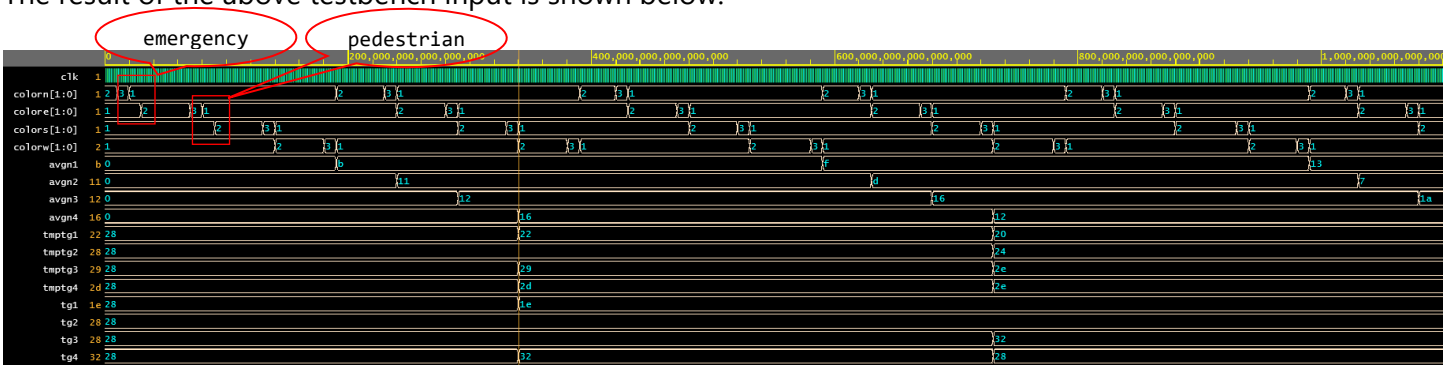
(For the purpose of simulation and verification, the value of k is chosen to be 2 instead of the default value)

The simulation is run with the following input to the testbench:

```
emgBit <= '0', '1' after 10 sec, '0' after 12 sec;
pedBit <= '0', '1' after 35 sec, '0' after 36 sec;

N1 <= 10,
    12 after 15 sec,
    14 after 215 sec,
    16 after 415 sec,
    18 after 615 sec,
    20 after 815 sec,
    22 after 1015 sec,
    24 after 1215 sec,
    22 after 1415 sec,
    20 after 1615 sec,
    18 after 1815 sec,
    16 after 2015 sec,

N2 <= 20,
    18 after 25 sec,
    16 after 225 sec,
    14 after 425 sec,
    12 after 625 sec,
    10 after 825 sec,
    5 after 1025 sec,
    6 after 1225 sec,
    8 after 1425 sec,
    10 after 1625 sec,
    12 after 1825 sec,
    14 after 2025 sec,

N3 <= 15,
    17 after 35 sec,
    19 after 235 sec,
    21 after 435 sec,
    23 after 635 sec,
    25 after 835 sec,
    27 after 1035 sec,
    25 after 1235 sec,
    23 after 1435 sec,
    21 after 1635 sec,
    19 after 1835 sec,
    17 after 2035 sec,

N4 <= 25,
    23 after 45 sec,
    21 after 245 sec,
    19 after 445 sec,
    17 after 645 sec,
    15 after 845 sec,
    13 after 1045 sec,
    11 after 1245 sec,
    13 after 1445 sec,
    15 after 1645 sec,
    17 after 1845 sec,
    19 after 2045 sec,

wait for 2200 sec;
```

Here, N1, N2, N3, and N4 denote the sensor readings from north, east, south, and west directions respectively.

The result of the above testbench input is shown below:



Here, 'colorn', 'colore', 'colors', and 'colorw' denote the signal color in north, east, south, and west directions respectively. 'avgn1', 'avgn2', 'avgn3', 'avgn4' are respective averages computed by the sensor units after completion of k (= 2) cycles. 'tmptg1', 'tmptg2', 'tmptg3', and 'tmptg4' are the outputs of the adaptive unit and represent updated T_{g_i} values respectively. Finally, 'tg1', 'tg2', 'tg3', and 'tg4' are the estimated values (in units of τ) 'tmptg1', 'tmptg2', 'tmptg3', and 'tmptg4' respectively.

The timer output for the north direction for the given testbench input is shown below:

```
system.vhd:165:8:@500ms:(report note): 39
system.vhd:165:8:@1500ms:(report note): 38
system.vhd:165:8:@2500ms:(report note): 37
system.vhd:165:8:@3500ms:(report note): 36
system.vhd:165:8:@4500ms:(report note): 35
system.vhd:165:8:@5500ms:(report note): 34
system.vhd:165:8:@6500ms:(report note): 33
system.vhd:165:8:@7500ms:(report note): 32
system.vhd:165:8:@8500ms:(report note): 31
system.vhd:165:8:@9500ms:(report note): 30
system.vhd:165:8:@10500ms:(report note): 10
system.vhd:165:8:@11500ms:(report note): 9
system.vhd:165:8:@12500ms:(report note): 8
system.vhd:165:8:@13500ms:(report note): 7
system.vhd:165:8:@14500ms:(report note): 6
system.vhd:165:8:@15500ms:(report note): 5
system.vhd:165:8:@16500ms:(report note): 4
system.vhd:165:8:@17500ms:(report note): 3
system.vhd:165:8:@18500ms:(report note): 2
system.vhd:165:8:@19500ms:(report note): 1
system.vhd:165:8:@20500ms:(report note): 10
system.vhd:165:8:@21500ms:(report note): 9
system.vhd:165:8:@22500ms:(report note): 8
system.vhd:165:8:@23500ms:(report note): 7
system.vhd:165:8:@24500ms:(report note): 6
system.vhd:165:8:@25500ms:(report note): 5
system.vhd:165:8:@26500ms:(report note): 4
system.vhd:165:8:@27500ms:(report note): 3
system.vhd:165:8:@28500ms:(report note): 2
system.vhd:165:8:@29500ms:(report note): 1
system.vhd:165:8:@30500ms:(report note): 150
system.vhd:165:8:@31500ms:(report note): 149
system.vhd:165:8:@32500ms:(report note): 148
system.vhd:165:8:@33500ms:(report note): 147
system.vhd:165:8:@34500ms:(report note): 146
system.vhd:165:8:@35500ms:(report note): 145
system.vhd:165:8:@36500ms:(report note): 144
system.vhd:165:8:@37500ms:(report note): 143
system.vhd:165:8:@38500ms:(report note): 142
system.vhd:165:8:@39500ms:(report note): 141
system.vhd:165:8:@40500ms:(report note): 140
```

abort green due to emergency

end of orange, beginning of emergency

The timer output for the east direction for the given testbench input is shown below:

```
system.vhd:165:8:@500ms:(report note): 49
system.vhd:165:8:@1500ms:(report note): 48
system.vhd:165:8:@2500ms:(report note): 47
system.vhd:165:8:@3500ms:(report note): 46
system.vhd:165:8:@4500ms:(report note): 45
system.vhd:165:8:@5500ms:(report note): 44
system.vhd:165:8:@6500ms:(report note): 43
system.vhd:165:8:@7500ms:(report note): 42
system.vhd:165:8:@8500ms:(report note): 41
system.vhd:165:8:@9500ms:(report note): 40
system.vhd:165:8:@10500ms:(report note): 10
system.vhd:165:8:@11500ms:(report note): 9
system.vhd:165:8:@12500ms:(report note): 8
system.vhd:165:8:@13500ms:(report note): 7
system.vhd:165:8:@14500ms:(report note): 6
system.vhd:165:8:@15500ms:(report note): 5
system.vhd:165:8:@16500ms:(report note): 4
system.vhd:165:8:@17500ms:(report note): 3
system.vhd:165:8:@18500ms:(report note): 2
system.vhd:165:8:@19500ms:(report note): 1
system.vhd:165:8:@20500ms:(report note): 10
system.vhd:165:8:@21500ms:(report note): 9
system.vhd:165:8:@22500ms:(report note): 8
system.vhd:165:8:@23500ms:(report note): 7
system.vhd:165:8:@24500ms:(report note): 6
system.vhd:165:8:@25500ms:(report note): 5
system.vhd:165:8:@26500ms:(report note): 4
system.vhd:165:8:@27500ms:(report note): 3
system.vhd:165:8:@28500ms:(report note): 2
system.vhd:165:8:@29500ms:(report note): 1
system.vhd:165:8:@30500ms:(report note): 40
system.vhd:165:8:@31500ms:(report note): 39
system.vhd:165:8:@32500ms:(report note): 38
system.vhd:165:8:@33500ms:(report note): 37
system.vhd:165:8:@34500ms:(report note): 36
system.vhd:165:8:@35500ms:(report note): 35
system.vhd:165:8:@36500ms:(report note): 34
system.vhd:165:8:@37500ms:(report note): 33
system.vhd:165:8:@38500ms:(report note): 32
system.vhd:165:8:@39500ms:(report note): 31
system.vhd:165:8:@40500ms:(report note): 30
system.vhd:165:8:@41500ms:(report note): 29
system.vhd:165:8:@42500ms:(report note): 28
system.vhd:165:8:@43500ms:(report note): 27
system.vhd:165:8:@44500ms:(report note): 26
```

red time reduced due to emergency in green

10 sec added in the red signal due to emergency

```
system.vhd:165:8:@45500ms:(report note): 25
system.vhd:165:8:@46500ms:(report note): 24
system.vhd:165:8:@47500ms:(report note): 23
system.vhd:165:8:@48500ms:(report note): 22
system.vhd:165:8:@49500ms:(report note): 21
system.vhd:165:8:@50500ms:(report note): 20
system.vhd:165:8:@51500ms:(report note): 19
system.vhd:165:8:@52500ms:(report note): 18
system.vhd:165:8:@53500ms:(report note): 17
system.vhd:165:8:@54500ms:(report note): 16
system.vhd:165:8:@55500ms:(report note): 15
system.vhd:165:8:@56500ms:(report note): 14
system.vhd:165:8:@57500ms:(report note): 13
system.vhd:165:8:@58500ms:(report note): 12
system.vhd:165:8:@59500ms:(report note): 11
system.vhd:165:8:@60500ms:(report note): 10
system.vhd:165:8:@61500ms:(report note): 9
system.vhd:165:8:@62500ms:(report note): 8
system.vhd:165:8:@63500ms:(report note): 7
system.vhd:165:8:@64500ms:(report note): 6
system.vhd:165:8:@65500ms:(report note): 5
system.vhd:165:8:@66500ms:(report note): 4
system.vhd:165:8:@67500ms:(report note): 3
system.vhd:165:8:@68500ms:(report note): 2
system.vhd:165:8:@69500ms:(report note): 1
system.vhd:165:8:@70500ms:(report note): 10
system.vhd:165:8:@71500ms:(report note): 9
system.vhd:165:8:@72500ms:(report note): 8
system.vhd:165:8:@73500ms:(report note): 7
system.vhd:165:8:@74500ms:(report note): 6
system.vhd:165:8:@75500ms:(report note): 5
system.vhd:165:8:@76500ms:(report note): 4
system.vhd:165:8:@77500ms:(report note): 3
system.vhd:165:8:@78500ms:(report note): 2
system.vhd:165:8:@79500ms:(report note): 1
system.vhd:165:8:@80500ms:(report note): 10
system.vhd:165:8:@81500ms:(report note): 9
system.vhd:165:8:@82500ms:(report note): 8
system.vhd:165:8:@83500ms:(report note): 7
system.vhd:165:8:@84500ms:(report note): 6
system.vhd:165:8:@85500ms:(report note): 5
system.vhd:165:8:@86500ms:(report note): 4
system.vhd:165:8:@87500ms:(report note): 3
system.vhd:165:8:@88500ms:(report note): 2
system.vhd:165:8:@89500ms:(report note): 1
```

10 sec pedestrian period followed by orange signal