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Indian Institute of Technology Kanpur
CS637 Embedded and Cyber-Physical Systems
Homework Assignment 4
Deadline: November 12, 2022

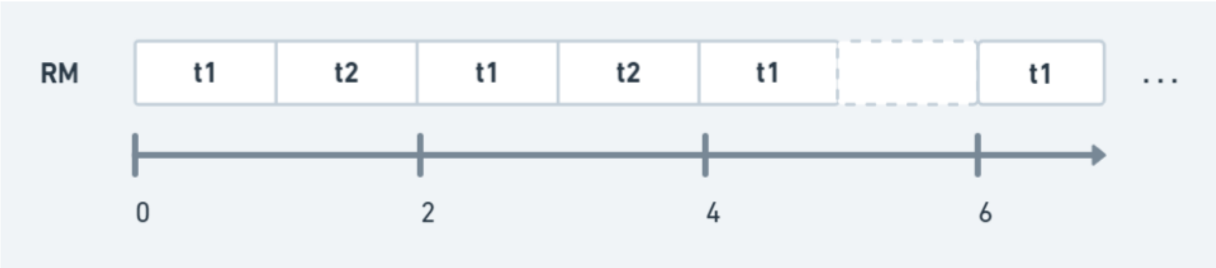
Total: **40 marks**

1. Write the answers **neatly** in the given boxes.
2. You may discuss the solutions with the other students, but you have to write them in your own words.

Problem 1. (10 points) Work out Problem 3 in the Exercises of Chapter 12 in [LS15]

(a) Give the RM schedule for this task set and find the processor utilization. How does this utilization compare to the Liu and Layland utilization bound of (12.2)?

Solution: The RM schedule is shown below:



The utilization is given by

$$U = \Sigma \frac{e_i}{p_i} = \left(\frac{e_1}{p1} + \frac{e_2}{p_2}\right)$$
$$= \frac{1}{2} + \frac{1}{3} \approx 83.33\%$$

The utilization bound if $n = 2$ is $n(2^{1/n} - 1) \approx 0.828$
Thus, utilization is larger than the utilization bound, so we have no assurance that the RM schedule is feasible.

(b) Show that any increase in e_1 or e_2 makes the RM schedule infeasible. If you hold $e_1 = e_2 = 1$ and $p_2 = 3$ constant, is it possible to reduce p_1 below 2 and still get a feasible schedule? By how much? If you hold $e_1 = e_2 = 1$ and $p_1 = 2$ constant, is it possible to reduce p_2 below 3 and still get a feasible schedule? By how much?

Solution: Task 1 has the greatest priority according to the RM principle and has twice been enabled in the first three time units, therefore the RM schedule is required to run it twice. Since $e_1 = 1$, job 2 may be completed in its first period in precisely one time unit. As a consequence, any rise in e_2 will cause task 2 to miss its deadline at time 3. Any increase in e_1 will result in job 2's initial period being less than one time unit long, again causing a missed deadline. We can lower p_1 to 1.5 while still obtaining a feasible schedule if we keep e_1, e_2, and p_2 unchanged. We can cut p_2 to 2 and still get a feasible schedule if we keep e_1, e_2, and p_1 unchanged. Since we now have 100% usage, no additional reduction is achievable in any scenario.

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(c) Increase the execution time of task 2 to be e2 = 1.5, and give an EDF schedule. Is it feasible? What is the processor utilization?

Solution: The EDF schedule is:

The schedule is feasible and the utilization is 100%.

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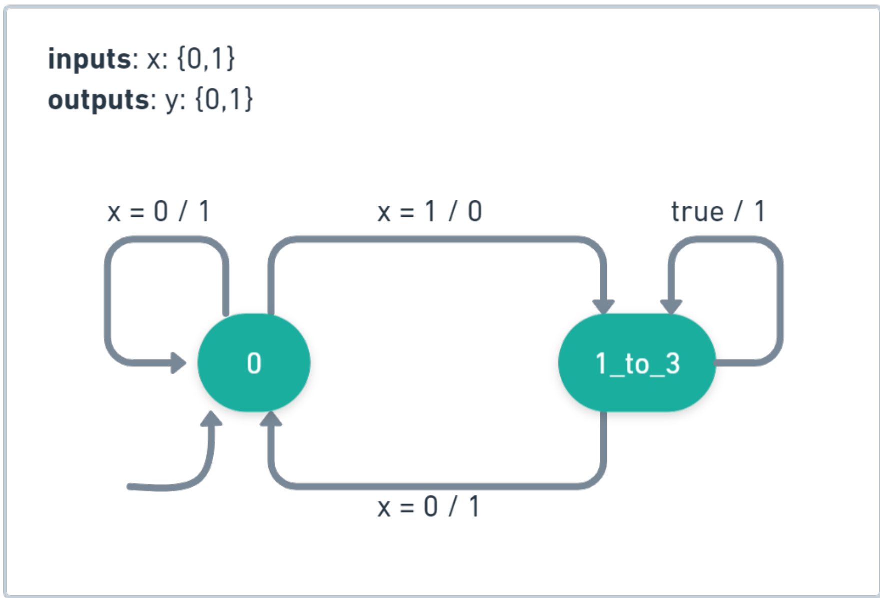
Problem 2. (10 points) Work out Problem 3 in the Exercises of Chapter 14 in [LS15].

The state machine is given by :



As shown by the state names, states 1, 2, and 3 are matched by 1 to 3, while state 0 is matched by 0. Consequently, the simulation relation will be{(0,0), (1_to_3,1), (1_to_3,2), (1_to_3,3)}
Since this machine has more observable traces than the machine shown in the given picture, the machines are not bisimilar.

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Problem 3. (10 points) Verify Fischer's Mutual Exclusion protocol using UPPAAL. The example is available with UPPAAL tool. Measure the time required to verify the protocol for increasing number of participants in the protocol.

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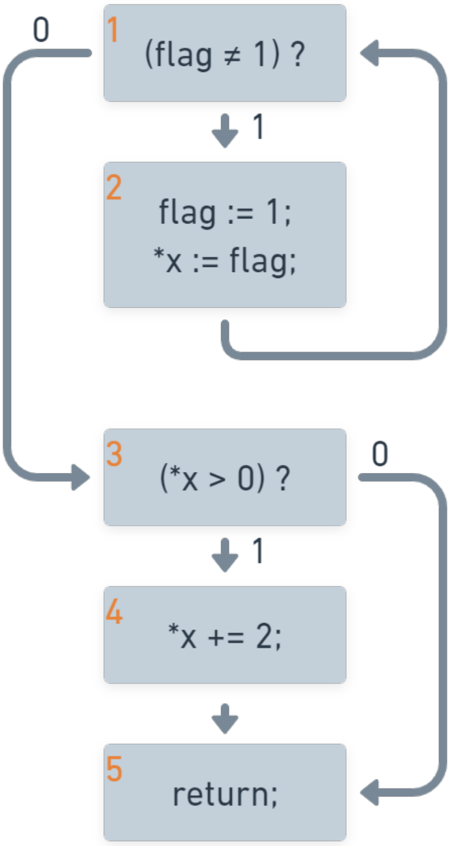
Problem 4. (10 points) Work out Problem 2 in the Exercises of Chapter 16 in [LS15].

(a) Draw the control-flow graph of this program. Identify the basic blocks with unique IDs starting with 1.

Solution: The control-flow graph is given by :



(b) Is there a bound on the number of iterations of the while loop? Justify your answer.

Solution: 1 is the upper limit for the number of iterations that may be performed. In the event that flag was not originally set to 1, the loop will be carried out, and the flag will be set to 1. As a result, the loop will need to leave the next time the condition is assessed.

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(c) How many total paths does this program have? How many of them are feasible, and why?

Solution: This program includes a total of four paths, corresponding to two possibilities for the while loop conditional and two choices for the if-statement conditional. The sole non-feasible route is 1-2-1-3-5, which corresponds to performing one iteration of the while loop (during which $*x$ is set to 1) and the else branch of the conditional $*x>0$. This cannot be run because after one iteration of the loop, $*x$ is bigger than 0.

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