Read all questions of the exam carefully before starting to answer.

- Provide detailed justifications to all answers.
- The use of bibliographic material, either in paper or in digital format is allowed.
- Exchange of information is forbidden (talk, WiFi, Bluetooth, GPRS, WAP,...).
- Exam duration: 3 hours.

Problem I

This problem will focus on the modeling and synthesis of a discrete event system: an automatic traffic light system must be installed on the confluence of two roads that give access to a narrow way, as depicted in the above figure. There are two sensors $S=\{S_L, S_R\}$, with binary outputs to detect the presence/absence of vehicles in the left and right way, respectively. There exists also installed two red lights $A=\{L_L, L_R\}$, one at each side, both with a digital ON/OFF command.

a) [1 point] Assume that a PLC must be installed, to implement the automatic traffic light system. Discuss its characteristics.

b) [1 point] Design an electrical diagram that details the proposed solution.

c) [1 point] Design a Petri net for the discrete event system described above, considering the information from the two sensors and the two ON/OFF traffic lights commands.

d) [2 points] Design a supervisor, based on the place invariant method studied in the course, such that independently for each side of the access, when the presence of a car is detected the light on the opposite side is commanded to become RED.

e) [1 point] Represent in the global Petri net obtained, the situation depicted in the figure above.
f) [2 points] There is a functional deadlock in the previous solution. Design a supervisor that implements a solution such that only one RED light can be commanded to ON.

g) [1 point] Discuss on how to generalize this problem, of 2 ways changing to 1, for the case where n ways are reduced to 1.

h) [1 point] Propose a simple Ladder, Structure Text or Instruction List segment of code that implements the supervisors synthesized.

Consider a=0.

a) [1 point] Discuss the conservativeness and the boundness of the aforementioned Petri net, resorting to a reachability (sub)tree.

b) [2 points] Discuss the liveness of each transition and the overall level of liveness for the Petri net.

Consider a=1.

c) [1 points] Discuss the conservativeness of the Petri net, for this case, and provide the weight vector.

d) [1 point] Resorting to the Method of the Matrix Equations, study if and how the marking \( u=[1 \ 1 \ 1]' \) can be reached.

e) [1 point] Build the reachability tree. Is the marking \( u=[0 \ 2 \ 0]' \) reachable?

f) [2 points] Find the cycles of operation or place invariants, for this Petri Net.

Consider a=2.

g) [1 point] Discuss the following statement “This Petri net is of level 3”.

h) [1 point] Discuss the liveness levels for a=0 and a greater or equal to 2.

Boa sorte!
Paulo Oliveira