You can review the latex source for this assignment-file to learn and use latex to prepare your homework submission. You will see the use of macros (to write uniformly formatted text), different text-styles (emphasized, bold-font), different environments (figures, enumerations).

It is not required that you use exactly this latex source to prepare your submission.

Homework 4 (CTL/LTL/BDD): ComS/CprE/SE 412, ComS 512

Due-date: April 18 at 11:59PM.

Submit online on Canvas two files: the source file in latex format and the pdf file generated from latex. Name your files: ⟨your-net-id⟩-hw4.⟨tex/pdf⟩.

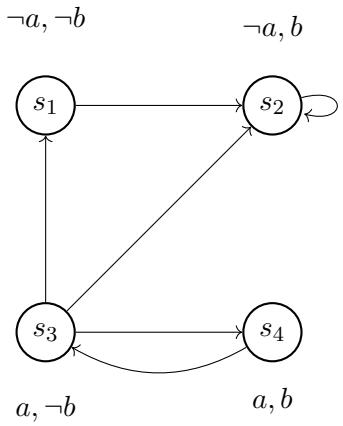
Homework must be individual's original work. Collaborations and discussions of any form with any students or other faculty members or soliciting solutions on online forums are not allowed. Please review the academic dishonesty policy on our syllabus. If you have any questions/doubts/concerns, post your questions/doubts/concerns on Piazza and ask TA/Instructor.

1. Draw the ROBDD for the following function.

$$f(x_1, x_2, x_3, x_4) = \begin{cases} 1 & \text{if the sum of } x_i\text{'s is equal to even} \\ 0 & \text{otherwise} \end{cases}$$

   In the above, the domain of x_i is $\{0, 1\}$. (5pts)

2. Identify the states in the following Kripke structure that satisfy the given formula. Justify your solution.



   (a) $\mathtt{G}(a)$

   (b) $(a \ \mathtt{U} \ b)$

   (c) $(a \ \mathtt{U} \ \mathtt{X}(a \wedge \neg b))$

   (d) $\mathtt{X}(a \wedge b) \ \wedge \ \mathtt{F}(\neg a \wedge \neg b)$

(10pts)

3. Prove or disprove the following claims.

   (a) $\mathtt{G}(\mathtt{F}(\mathtt{X}(p)))$ and $\mathtt{G}(\mathtt{X}(\mathtt{F}(p)))$ are equivalent.

   (b) $\mathtt{G}(\mathtt{F}(p)) \Rightarrow \mathtt{G}(\mathtt{F}(q))$ and $\mathtt{F}(\mathtt{G}(\neg p)) \Rightarrow \mathtt{F}(\mathtt{G}(q))$ are equivalent.

   (c) Given any Kripke structure, one can verify whether a state satisfies the CTL formula $\mathtt{AF}(\mathtt{AG}(p))$ using the LTL formula $\mathtt{G}(\mathtt{F}(\neg p))$. (Note that, the question is not asking whether the two formulas are equivalent or not).

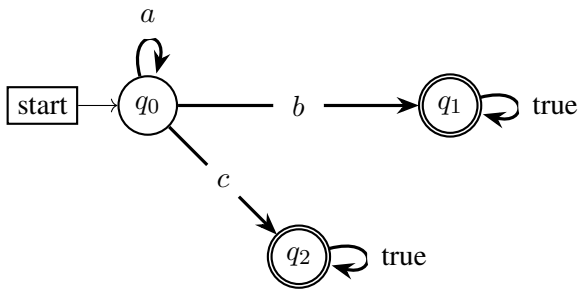
   (d) A state satisfies $(\mathtt{AG}(p)) \Rightarrow (\mathtt{AF}(q))$ if and only if the state satisfies $(\mathtt{G}(p)) \Rightarrow (\mathtt{F}(q))$.

   (e) A state satisfies $((\neg q)\ \mathtt{U}\ (\neg p \wedge \neg q))$ implies that the state satisfies $\neg(p\ \mathtt{U}\ q)$.

(20pts)

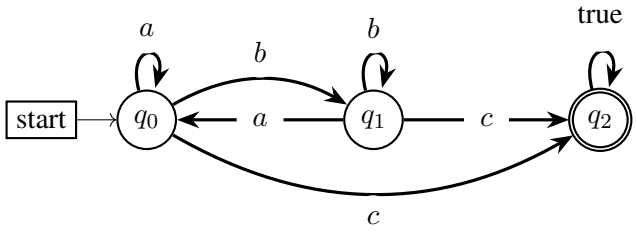
4. Identify the LTL formulas whose semantics is represented in the language of the following automata. Justify your solution. (*The start states are denoted by the states which have an incoming edge from the "start". The edge labels indicates a boolean formula; for instance, q_0 on boolean formula a has an edge to itself in the A_1)*)

   (a) Automata A_1



(5pts)

   (b) **512 Question. Extra Credit for 412.** Automata A_2 (*Hint: Look closely at the states q_0 and q_1. What type of patterns over a and b originate from q_0 and q_1?*)



(10pts)