HW #5: Due Dec 14th 11:00 AM

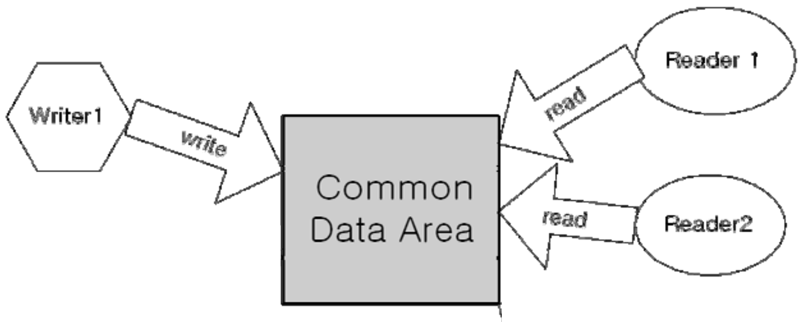
1. Draw the transition system described by the ABP program.

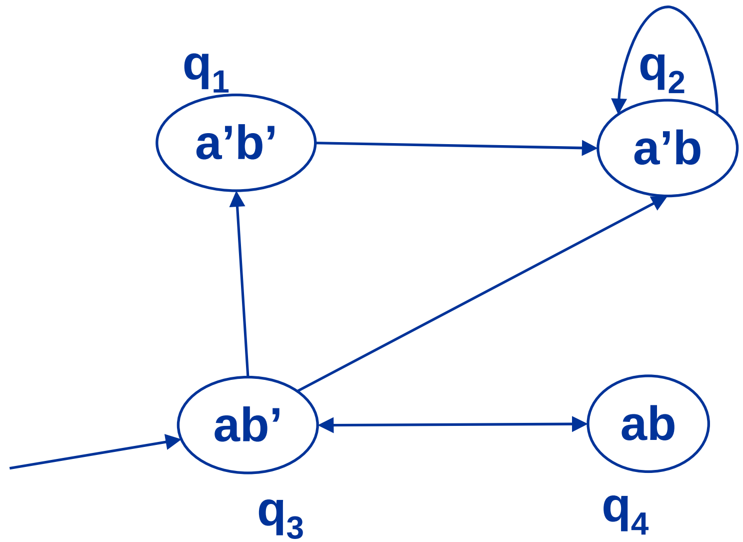
   Remarks: There are 28 reachable states of the ABP program. (Looking at the program, you can see that the state is described by nine boolean variables, namely `S.st`, `S.message1`, `S.message2`, `R.st`, `R.ack`, `R.expected`, `msg_chan.output1`, `msg_chan.output2` and finally `ack_chan.output`. Therefore, there are $2^9 = 512$ states in total. However, only 28 of them can be reached from the initial state by following a finite path.)

   If you abstract away from the contents of the message (e.g. by setting `S.message1` and `msg_chan.output1` to be constant 0), then there are only 12 reachable states. This is what you are asked to draw.

2. Model and verify 2 readers and 1 writer system in NuSMV

- 2-1. Design a system containing 2 readers and 1 writer that access the common data in NuSMV
- 2-2. Specify the following two properties in LTL and show that your system satisfies these properties
  - Concurrency (CON)
    - Multiple readers can read data concurrently
  - Exclusive writing (EW)
    - A writer can write into the data area at an instant with no readers





3 For each of the formula ϕ

- G a
- a U b
- a U X (a $\wedge$ $\neg$b)
- X $\neg$b $\wedge$ G ($\neg$a $\vee$ $\neg$b)
- X (a $\wedge$ b) $\wedge$ F ($\neg$a $\wedge$ $\neg$b)

1) Find a path from the initial state q_3 which satisfies ϕ
2) Determine whether $q_3 \vDash \phi$

4. Prove that ϕ U $\psi \equiv \psi$ R $(\phi \vee \psi) \wedge$ F ψ

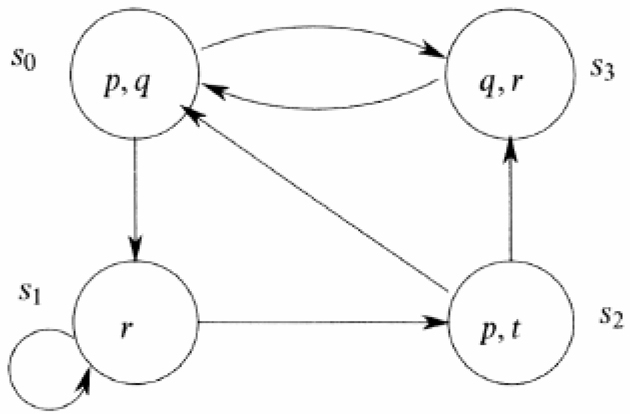
5. Prove that for all paths π of all models, $\pi \vDash \phi$ W $\psi \wedge$ F ψ implies $\pi \vDash \phi$ U ψ

6. (a) Beginning from state s_0, unwind this system into an infinite tree, and draw all computation paths up to length 4 (= the first four layers of that tree).

(b) Make the following checks $\mathcal{M}, s_0 \vDash \phi$, where ϕ is listed below. For that you need to explain why the check holds, or what reasons there are for its failure:

- * (i) $\neg p \to r$
- (ii) $\mathrm{AF}\, t$
- *(iii) $\neg \mathrm{EG}\, r$
- (iv) $\mathrm{E}(t \,\mathrm{U}\, q)$
- (v) $\mathrm{AF}\, q$
- (vi) $\mathrm{EF}\, q$
- (vii) $\mathrm{EG}\, r$
- (viii) $\mathrm{AG}\,(r \vee q)$.

(c) Make the same checks as in (b) but now for state s_2.



7. Express the following properties in CTL and LTL whenever possible. If neither is possible, try to express the property in CTL*

   a) Whenever p is followed by q (after finitely many steps), then the system enters an 'interval' in which no r occurs until t

   b) Event p precedes s and t on all computation paths. (you many find it easier to code the negation of that specification first)

   c) After p,q is never true (Where this constraint is meant to apply on all computation paths)

   d) Between the events q and r, event p is never true.

   e) Transitions to states satisfying p occur at most twice.

   f) Property p is true for every second state along a path

8. Find a transition system which distinguishes the following pairs of CTL* formulas (i.e. show that they are *not* equivalent):

(a) $\mathrm{AFG}\,p$ and $\mathrm{AF\,AG}\,p$

* (b) $\mathrm{AGF}\,p$ and $\mathrm{AG\,EF}\,p$

(c) $\mathrm{A}[(p \mathrel{\mathrm{U}} r) \vee (q \mathrel{\mathrm{U}} r)]$ and $\mathrm{A}[(p \vee q) \mathrel{\mathrm{U}} r)]$

* (d) $\mathrm{A}[X\,p \vee \mathrm{XX}\,p]$ and $\mathrm{AX}\,p \vee \mathrm{AX\,AX}\,p$

(e) $\mathrm{E}[\mathrm{GF}\,p]$ and $\mathrm{EG\,EF}\,p$.