

# HW #5: Due May 24th 23:59 AM

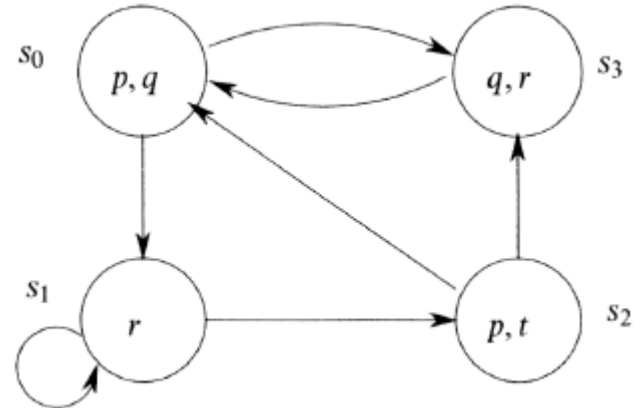
1. Prove that  $\phi \text{ U } \psi \equiv \psi \text{ R } (\phi \vee \psi) \wedge \text{ F } \psi$
2. Prove that for all paths  $\pi$  of all models,  $\pi \models \phi \text{ W } \psi \wedge \text{ F } \psi$  implies  $\pi \models \phi \text{ U } \psi$

3. (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  $\mathcal{M}, s_0 \models \phi$ , where  $\phi$  is listed below. For that you need to explain why the check holds, or what reasons there are for its failure:

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

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



4. 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 may 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
  
5. Find a transition system which distinguishes the following pairs of CTL\* formulas (i.e. show that they are *not* equivalent):
  - (a)  $AF G p$  and  $AF AG p$
  - \* (b)  $AG F p$  and  $AG EF p$
  - (c)  $A[(p U r) \vee (q U r)]$  and  $A[(p \vee q) U r]$
  - \* (d)  $A[X p \vee XX p]$  and  $AX p \vee AX AX p$
  - (e)  $E[GF p]$  and  $EG EF p$ .