

NATIONAL UNIVERSITY OF SINGAPORE  
SCHOOL OF COMPUTING

**SPIN/LTL Exercises posted for cs4271 students Semester 2, 2010/2011**

(1) Are the two following Linear time Temporal Logic formula equivalent ? If yes, give a proof. If not, construct example traces to show that they are not equivalent.

$$\mathbf{F}(p\mathbf{U}q) \Leftrightarrow \mathbf{F}p \mathbf{U} \mathbf{F}q$$

You can assume that  $p$  and  $q$  are atomic propositions.

(2) In class, we discussed the nested depth-first search algorithm implemented inside the model checker SPIN. Among other things, this allows us to easily retrieve the counter-example trace from the stack. Suppose we implemented breadth-first search with queues instead for the purpose of model checking. Will the task of counter-example computation become any more difficult? Explain your answer.

(3) Recall the definition of the Until operator  $\mathbf{U}$  in Linear-time temporal logic (LTL). Let us now define a new until operator  $\mathbf{U}_1$  as follows:

$M, \pi \models \varphi \mathbf{U}_1 \psi \equiv$  if there exists a  $k \geq 0$  such that  $M, \pi^k \models \psi$  then for all  $0 \leq j < k$  we have  $M, \pi^j \models \varphi$

The notation  $\pi^k$  was discussed in class (and also appears in the textbook). Express  $\varphi \mathbf{U}_1 \psi$  as a Linear-time temporal logic (LTL) formula and give explanation for your answer. You may assume that  $\varphi, \psi$  are arbitrary LTL properties.

(4) Assume  $p$  is an atomic proposition. Describe the following property in LTL: “along any path, a state satisfying  $p$  occurs at most once”. Explain your answer.