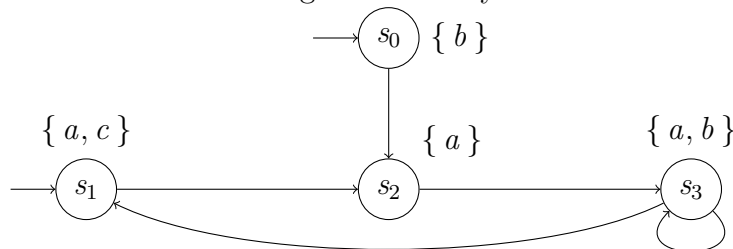




Tutorials for Model Checking
Exercise sheet 4

Exercise 1: CTL

Consider the following transition system over the set of atomic propositions $\{a, b, c\}$:



Give for each of the following CTL-formulae the set of states for which the formula is satisfied.

- | | | |
|---------------------|-------------------------|------------------------|
| (a) $a \wedge EX b$ | (b) $EX c$ | (c) $AX EX c$ |
| (d) $a AU b$ | (e) $b AU a$ | (f) $b AU (AG a)$ |
| (g) $a AU (EG b)$ | (h) $\neg(a EU (EG b))$ | (i) $(EF c) AU (AG a)$ |
| (j) $AF AG a$ | (k) $AG AF b$ | (l) $AG EF c$ |

Exercise 2: CTL Equivalences

Given an arbitrary atomic proposition p , prove that the following equivalences hold:

$$EF AG EF AG p \equiv EF AG p$$

$$AG EF AG EF p \equiv AG EF p$$

Hint: Prove the following implications first.

$$EF AG p \Rightarrow EF p \tag{1}$$

$$AG p \Rightarrow AG EF AG p \tag{2}$$

Note that for two arbitrary CTL formulas ϕ and ψ , we say that $\phi \Rightarrow \psi$ iff for all Kripke structures \mathcal{K} and states s , $s \in \llbracket \phi \rrbracket_{\mathcal{K}}$ implies $s \in \llbracket \psi \rrbracket_{\mathcal{K}}$.

Exercise 3: Binary Decision Diagrams

Consider the boolean formula $x \leftrightarrow (y \wedge z)$:

- (a) Draw a BDD (Binary Decision Diagram) for the formula with variable ordering $x < y < z$.
- (b) Find another variable ordering which results in a smaller BDD. Draw the corresponding BDD.