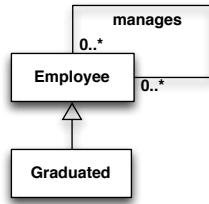


**Exercise 1.** Consider the following simple UML class diagram, and express in *FOL* the following boolean queries (stating which ones are CQs):

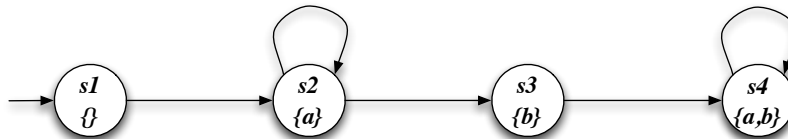


1. Return employees that manage at least one employee.
2. Return employees that manage at exactly one employee.
3. Return employees that manage at exactly two employees
4. Return employees that manage only employees that are not graduated.
5. Check if there exists an employee that manages all employees that are not graduated.

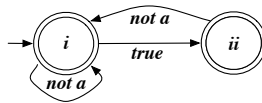
**Exercise 2.** By using tableaux, check whether the *FOL* formula below is valid, and if not, construct a counter model.

$$((\forall y.A(y)) \equiv (\forall z.B(z))) \supset (\forall x.(A(x) \equiv B(x)))$$

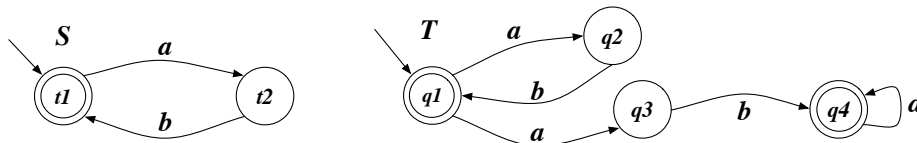
**Exercise 3.** Model check the Mu-Calculus formula  $\mu X.\nu Y.(a \vee [next]X) \wedge [next]Y$  and the CTL formula  $AFAGEXa$  against the following transition system:



**Exercise 4.** Consider the transition system of Exercise 3. Model check the *LTL* formula  $\diamond(a \wedge \bigcirc a)$ , by considering that the Büchi automaton for  $\neg \diamond(a \wedge \bigcirc a)$  is the one below:



**Exercise 5.** Consider the following two transition systems:



Write the definition of bisimilarity and compute the bisimilarity relation for the two transition systems.

**Exercise 6.** Compute the weakest precondition for getting  $\{x = 0\}$  by executing the following program:

```

x := 1 - y;
if (x > 1) then
    x := x - y;
else x := x + y;
y := y + 1
    
```