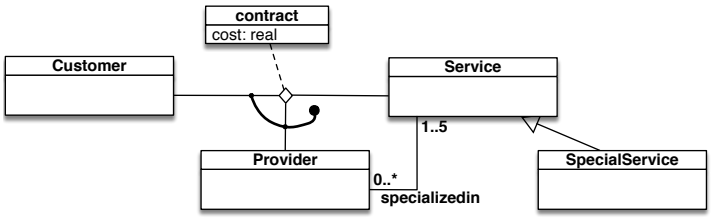
SAPIENZA Università di Roma – MSc. in Engineering in Computer Science

Formal Methods – June 17, 2019

(Time to complete the test: 2 hours)

Exercise 1. Express the following UML class diagram in FOL:



Exercise 2. Consider the above UML class diagram and the following (partial) instantiation:

Customer

c1
c2
c3
c4

Service

s1
s2
s3

SpecialService

ss1
ss2

Provider

p1
p2

specializedin

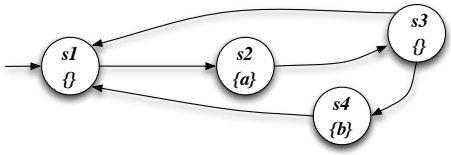
p1	s1
p1	s2
p1	s3
p2	ss1
p2	ss2

contacts/cost

c1	p1	s1	90.0
c1	p2	s2	80.0
c2	p1	s1	50.0
c3	p2	ss1	170,0
c2	p2	ss2	100,0

1. Check whether the above instantiation, once completed, is correct, and explain why it is or it is not.
2. Express in FOL the following queries and evaluate them over the completed instantiation:
   (a) Return those providers that have contracts with at least two customers.
   (b) Return those providers that have contracts only services they are specialized in.
   (c) Return those providers that have contracts all services they are specialized in.
   (d) Check whether there exists a customer with contracts for all services.

Exercise 3. Model check the Mu-Calculus formula $\nu X.\mu Y.((a \wedge \langle next \rangle X) \vee (\neg b \wedge \langle next \rangle Y)$ and the CTL formula $AG(AFa \wedge EFb \wedge EG\neg b)$ (showing its translation in Mu-Calculus) against the following transition system:



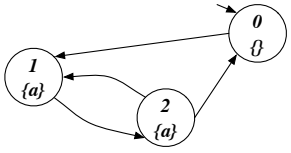
Exercise 4. Check whether CQ q_1 is contained in CQ q_2, reporting canonical DBs and homomorphism:

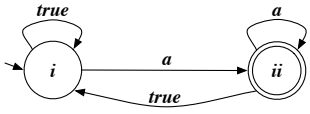
$$q_1() \leftarrow edge(r,g), edge(g,b), edge(b,r).$$
$$q_2() \leftarrow edge(x,y), edge(y,z), edge(z,x), edge(z,v), edge(v,w), edge(w,z).$$

Exercise 5. Check whether the following FOL formula is valid, by using tableaux:

$$(\forall x.\forall y.P(x,y) \supset Q(x)) \equiv (\forall x.(\exists y.P(x,y)) \supset Q(x))$$

Exercise 6 (optional). [1] Model check the LTL formula $\Diamond\Box\neg a$ against the following transition system, by considering that the Büchi automaton for $\neg(\Diamond\Box\neg a)$ is the one below:





[1] *The student can get the maximum grade even without doing Exercise 6.*