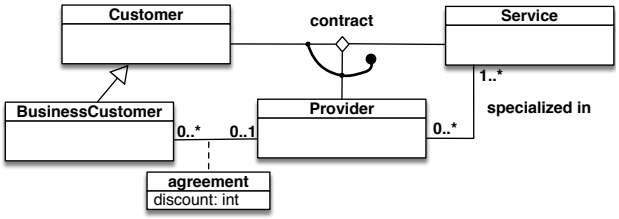
SAPIENZA Università di Roma – MSc. in Engineering in Computer Science

Formal Methods – July 12, 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

$BusiCustumer$

b1
b2

$Provider$

p1
p2

$agreement/disc$

b1	p1	30

$Service$

s1
s2
s3
s4
s5

$specializedin$

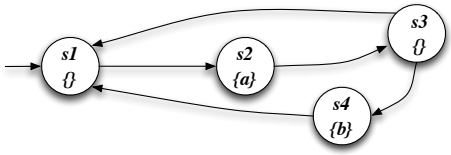
p1	s1
p1	s2
p1	s3
p2	s4
p2	s5

$contacts$

c1	p1	s1
c1	p2	s2
c2	p1	s1
b1	p1	s4
b2	p2	s5

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 are specialized in at least two services.
   (b) Return those business customers that have contracts only with providers with whom they have an agreement.
   (c) Return those business customers that have contracts with all providers with whom have an agreement .
   (d) Check whether there exists a customer with contracts for all services.

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



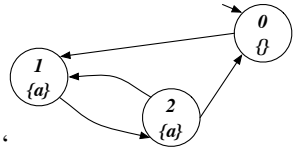
Exercise 4. Check whether the Hoare triple below is correct, by using $(x \geq 0 \wedge y \geq 0 \wedge x + y = 23)$ as invariant:

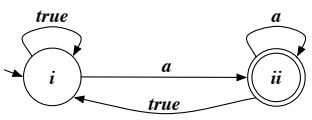
$$\{x = 23 \wedge y = 0\}\ \texttt{while(x>0) do (x=x-1; y:= y+1)}\ \{y = 23\}$$

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

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

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.*