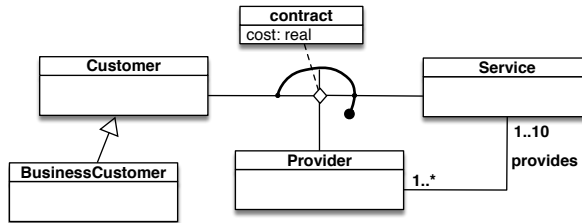


Exercise 1. Express the following UML class diagram in FOL:

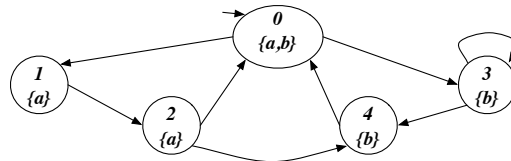


Exercise 2. Consider the above UML class diagram and the following (partial) instantiation:

Customer	BCustomers	Services	Provider	provides	contacts/cost
c1	b1	s1	p1	p1 s1	c1 s1 p1 90.0
c2	b2	s2	p2	p1 s2	c1 s2 p1 80.0
c3	b3	s3		p1 s3	c1 s3 p1 50.0
c4				p2 s2	b2 s1 p2 170.0
					b2 s2 p2 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) Check whether there is a customer with contract with two providers for the same service.
 - (b) Return those customers that have contracts only for one service.
 - (c) Return those customers that have a contracts with the same provider for all their services.

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



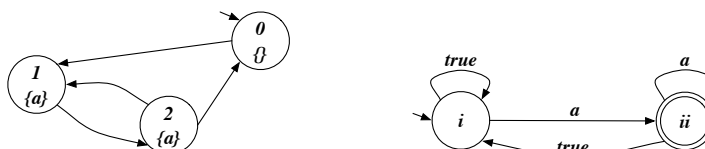
Exercise 4. Check whether CQ q_1 is contained in CQ q_2 , reporting canonical DBs and homomorphism:

$$\begin{aligned}
 q_1(x_r) &\leftarrow e(x_r, x_g), e(x_g, x_b), e(x_b, x_r). \\
 q_2(x) &\leftarrow e(x, y), e(y, z), e(z, x), e(z, v)e(v, w), e(w, z).
 \end{aligned}$$

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

$$(\forall x. P(x) \supset Q(x)) \supset (\exists x. P(x) \supset \exists x. Q(x))$$

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



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