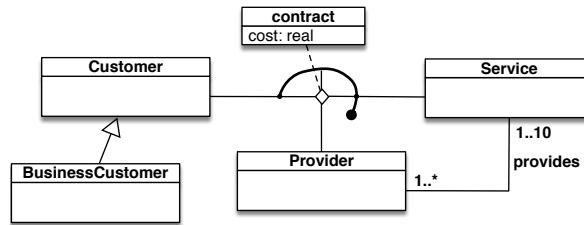


Exercise 1. Express the following UML class diagram in FOL:

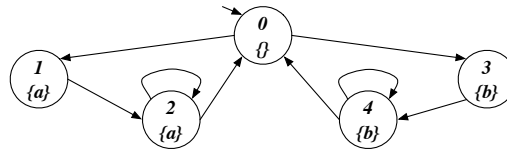


Exercise 2. Consider the above UML class diagram and the following (partial) instantiation:

Customer	BCustomers	Services	Provider	provides	contracts/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

- Check whether the above instantiation, once completed, is correct, and explain why it is or it is not.
- Express in FOL the following queries and evaluate them over the completed instantiation:
 - Check that, for every provider x and service y involved in a contract, provider x does provide service y .
 - Return those customers that have contracts only for services provided by $p2$.
 - Return those customers that have a contract for with all providers.

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



Exercise 4. Check whether the Hoare triple below is correct, by using $(x \geq 0 \wedge y \geq 0 \wedge x + y = 31)$ as invariant:

$$\{x = 31 \wedge y = 0\} \text{ while}(x > 0) \text{ do } (x = x - 1; y := y + 1) \{y = 31\}$$

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

$$(\exists x. P(x) \vee \exists x. Q(x)) \equiv \exists x. (P(x) \vee Q(x))$$

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

