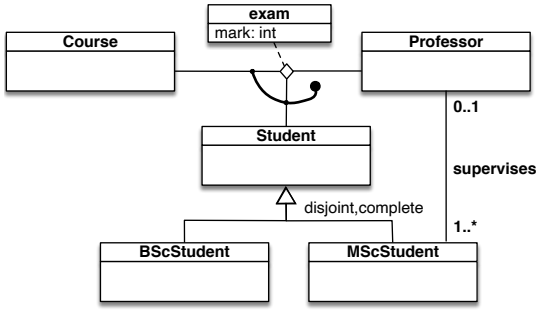
SAPIENZA Università di Roma – MSc. in Engineering in Computer Science

Formal Methods – June 26, 2020

(Time to complete the test online: 2:30 hours)

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



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

$BScStudent$

sb1
sb2

$MScStudent$

sm1
sm2
sm3

$Professor$

p1
p2

$Course$

c1
c2

$supervises$

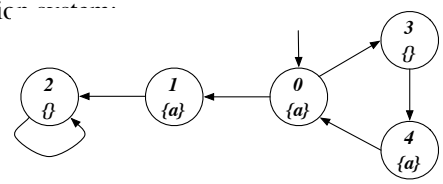
p1	sm1
p2	sm2
p1	sm3

$exam/mark$

sm1	c1	p1	30
sm1	c2	p2	28
sm2	c1	p1	30
sb1	c1	p2	27

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 students that have taken an exam with mark 30.
   (b) Return those students that have taken at least three exams.
   (c) Check if there is a professor that has supervised all students.
   (d) Check if there is a professor that has supervised only students that have taken an exam with mark 30.

Exercise 3. Consider the following transitic- -----:



1. Model check the Mu-Calculus formula: $\nu X.\mu Y.((a \wedge [next]X) \vee \langle next \rangle Y)$
2. Model check (by translating it in Mu-Calculus) the CTL formula: $EG(a \wedge AFa)$

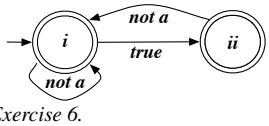
Exercise 4. Compute the *weakest precondition* for getting x=y executing the following program:

```
x:=10;
if (y>10) then {
  x=x+y;
  y=y-5
}
else x=x-y
```

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

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

Exercise 6 (optional). 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:[1]



Not optional anymore

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