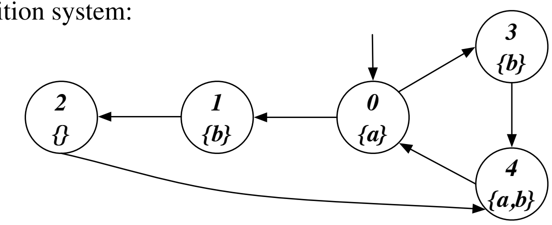
SAPIENZA Università di Roma – MSc. in Engineering in Computer Science

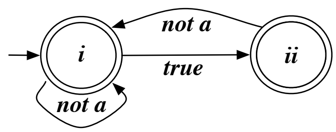
Formal Methods – February 9, 2024

(Time to complete the test online: 2:00 hours)

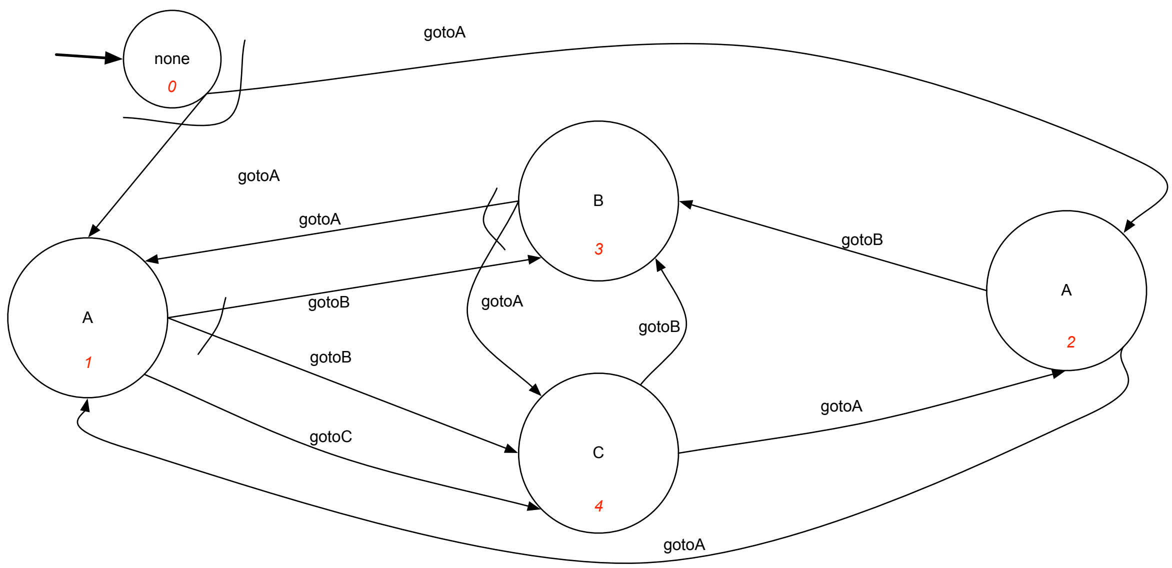
Part 1. Consider the following transition system:



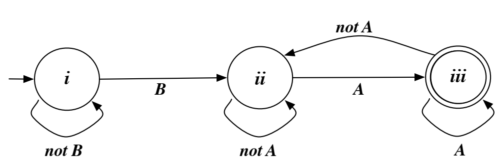
- **Exercise 1.1:** Model check the CTL formula $AG(EG(AFa \vee EFb))$ by translating it in Mu-Calculus.
- **Exercise 1.2:** Model check the LTL formula $\Diamond(a \wedge \bigcirc a)$, by considering that the Büchi automaton for $\neg\Diamond(a \wedge \bigcirc a))$ is:



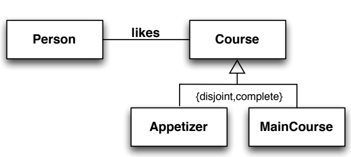
Part 2. Consider the following domain:



Synthesize a strategy for realizing the LTLf formula $\Diamond(B \wedge \circ\Diamond(A \wedge \bullet \mathit{false}))$ by considering that the corresponding DFA is:



Part 3. Consider the following simple UML class diagram, and express in FOL the following boolean queries stating which ones are CQs (do not use abbreviations for cardinalities):



1. *Return persons who like an appetizer and a main course.*
2. *Check if there exists a person who likes two appetizers and a main course.*
3. *Check if there exists a person who likes exactly one appetizer.*
4. *Return persons who like all appetizers.*
5. *Return persons who likes only appetizers.*
6. *Check if there is a pair of persons such that the first likes all appetizers that the second likes.*

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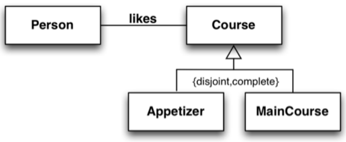

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1 $\exists a, m. P(x) \land APP(a) \land MAIN(m) \land LIKES(x, a) \land LIKES(x, m)$ ✓

2. $\exists p, a, a', m. P(p) \land APP(a) \land APP(a') \land MAIN(m) \land a \neq a' \land$
$\land LIKES(p, a) \land LIKES(p, m) \land LIKES(p, a')$ ✗

3. $\exists p, a. P(p) \land APP(a) \land LIKES(p, a) \land$
$\land \forall a' (APP(a') \land LIKES(p, a') \supset a = a')$ ✗

4. $P(x) \land \forall a. (APP(a) \supset LIKES(x, a))$ ✗

5. $P(x) \land \forall a. (LIKES(x, a) \supset APP(a))$ ✗

6. $\exists p, p'. P(p) \land P(p') \land \forall a. (APP(a) \land LIKES(p', a) \supset LIKES(p, a))$ ✗