SAPIENZA Università di Roma – MSc. in Engineering in Computer Science
Formal Methods – December 16, 2015 - Final Test A
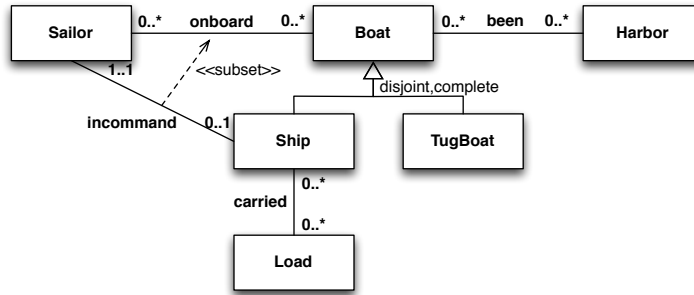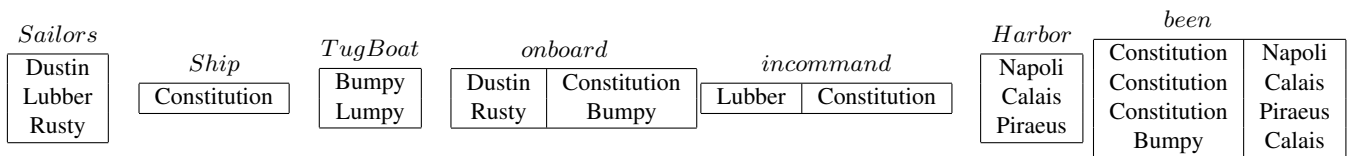*(Time to complete the test: 2 hours)*

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

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


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 the sailors that have been on board of a boat which has been in Piraeus.

   (b) Check whether there exists a harbor in which there have been at least two boats.

   (c) Return the boats that have been in all harbors.

Exercise 3. Model check the Mu-Calculus formula $\nu X.\mu Y.((a \wedge \langle next \rangle X) \vee ([next]Y))$ and the CTL formula $EF(AG(a \supset AX \neg a))$ (showing its translation in Mu-Calculus) against the following transition system:
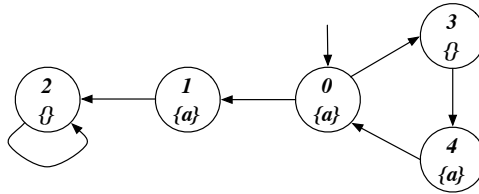
Exercise 4. Consider the following transition systems:
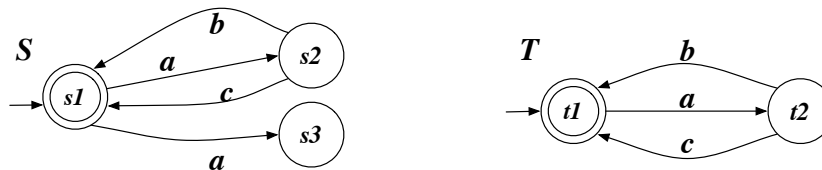
Write the definition of bisimilarity and compute the bisimilarity relation for the two transition system.

Exercise 5. Given the following boolean conjunctive queries (with a and b constants):

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q1() :- e(a,y),e(x,y),e(x,b)
q2() :- e(a,y),e(x,y),e(x,z),e(w,z),e(w,b)
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check whether $q1$ is contained into $q2$, explaining the technique used and, in case of containment, showing the homomorphism between the canonical databases.